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Development of a Field Laundry Wastewater Recycling System

by
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A field laundry wastewater recycling system (FLWRS) using powdered activated carbon, a cationic and an anionic polyelectrolyte, and diatomaceous earth filter was evaluated to determine the effectiveness of the process to produce recycled water for reuse in military field laundry operations. Analysis of the results of six batch runs with various treatment cycles indicated that the FLWRS batch treatment process can be operated effectively to treat laundry wastewater for recycle use in laundry units in the field.

A task and skill analysis was performed to develop a training program for military laundry operators. A training course of 40 hours duration would be sufficient to enable a laundry specialist to become proficient in operating a FLWRS. No health hazard was anticipated to result from the use of detergents, bleaches, soaps, and water treatment chemicals during operation of the FLWRS.

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FOREWORD

This research was conducted for the Army Water Office, DALO-TSE-W, of the Office of the Deputy Chief of Staff for Logistics (ODCSLOG) under Project Identification Number CERL-84-4-012; and for the U.S. Air Force Engineering and Services Center (AFESC), Tyndall AFB, FL under Job Order Number 2103 8025. MAJ Michael Murphy, DALO-TSE-W, and LT Al Rhodes, AFESC-RDVW, were the Technical Monitors.

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Dr. R. K. Jain is Chief of USA-CERL-EN. COL Paul J. Theuer is Commander and Director of USA-CERL, and Dr. L. R. Shaffer is Technical Director. COL Robert G. Gilbert is Commander of AFESC, and COL Robert E. Boyer is Director, AFESC Engineering and Services Laboratory.

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DEVELOPMENT OF A FIELD LAUNDRY WASTEWATER RECYCLING SYSTEM

1 INTRODUCTION

Background

Since World War I, fresh water supplies have been relatively abundant in areas where the U.S. Army has conducted military operations. Thus, little attention has been given to availability of water supplies or water sources, and especially to the need to regulate water use in the field. Recently, however, the Army has directed more attention to water resource management due to the increased logistics costs of supplying and transporting water to combat areas and the growing prospect that it may have to deploy forces to the Middle East or other arid regions. Water conservation, recycling, and reuse are some of the water resource management options being examined.

Water supply and distribution are expected to be a major logistics effort in most water-short or water-critical areas of the world. Laundry operations are large users of water that could benefit from water management techniques. For example, one section of an Army field laundry (two washers and driers) operating 20 hours requires 10,000 gal* of water per day. However, a laundry wastewater recycling process can potentially save thousands of gallons of water per day for each field laundry unit and, at the same time, minimize the amount of wastewater discharged into the environment.

In 1975, the Army began developing a field laundry wastewater treatment kit (not in Air Force inventory) to remove pollutants from laundry wastewater (detergents, oils, etc.) before it is discharged to the ground or released to streams or lakes. The treatment involves a batch process in which anionic and cationic polymers, along with powdered activated carbon, are added manually to each 500 gal of collected wastewater. The resulting treated water can be further treated (polished) using a diatomaceous filter and disinfected with chlorine for reuse for laundry purposes.

To use this treatment process in a field laundry wastewater recycling system (FLWRS) in field operations, the Army must first conduct a full-scale evaluation to verify the effectiveness of the treatment process and equipment.

Objectives

The objectives of this study were to:

1. Determine the effectiveness of the FLWRS to produce water meeting U.S. Army Office of the Surgeon General (OTSG) interim quality criteria for direct reuse of reclaimed wastewater in military field laundries

2. Develop an appropriate training program for military personnel who will operate the proposed laundry wastewater recycling system

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*Metric conversion factors are provided on p 64.

3. Identify essential analytical tests and equipment required by system operators in the field

4. Assess the potential health implications of the proposed system for recycling laundry wastewater.

Approach

The FLWRS was tested to verify its effectiveness in treating laundry wastewaters for reuse and the data analyzed.

A suggested program of instruction for military operators was then developed based on a "Task and Skill Analysis"[1] of the deployment, operation, disassembly and repacking of the proposed hardware system. Based on the laboratory results, tests and testing equipment required during field deployment of the system were identified.

Potential health hazards associated with field use of the system were determined based on a review of literature dealing with health implications of the chemicals expected to occur in typical field laundry wastewaters.

Scope

The information in this report represents only the initial stages in the development of a field laundry wastewater recycling system. Additional work is under way to further confirm the safety of the concept, and field testing will determine whether the system, as currently configured, can be operated successfully by laundry unit personnel.

Mode of Technology Transfer

It is recommended that following completion of the development, procurement, and testing of the FLWRS, existing Field Manuals pertaining to laundry be amended or a new manual developed to include guidance in the use of this wastewater renovation equipment.

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[1] Army Regulation (AR) 611-101, *Commissioned Officer Specialty Classification System* (Department of the Army [DA], 30 October 1984); AR 611-112, *Manual of Warrant Officer Military Occupational Specialities* (DA, 30 October 1984); AR 611-201, *Enlisted Career Management Fields and Military Occupational Specialties* (DA, 10 June 1984).

2 TESTING SETUP AND PROCEDURES

The treatment protocol consisted of a batch process employing the manual addition of anionic and cationic polymers along with powdered activated carbon to each 500 gal of collected wastewater. The tests were designed to verify the effectiveness of the wastewater renovation process and of the equipment identified[2] as being suitable for use in field laundry operations. Pollutants were removed by flocculation, settling, and the adsorption of organic substances by the activated carbon. The water was then treated (polished) using a diatomaceous filter and disinfected with chlorine.

Samples from laundry discharge (washer effulent), initially treated (settled), and filtered waters were analyzed by standard testing methods to determine the effectiveness of the treatment system. Although the water quality criteria prescribed by OTSG set limits on only turbidity, pH, and chlorine residual, a more comprehensive array of parameters was evaluated.

Equipment and Assembly

Figure 1 shows the test setup used at the research laboratory of the Civil Engineering Department at the Virginia Military Institute (VMI), Lexington, VA, where the testing was conducted.

Several variations from normal field laundry operations were made to accommodate the lack of a standard-issue, trailer-mounted M-532 Laundry Unit and to conduct the testing in a laboratory setting. A commercial/industrial, front-loading washer/extractor of 70-lb capcity and a 42-gal electric hot water heater were used in lieu of the M-532 Laundry Unit. Also, commercial electric power was used to operate the washer/extractor and pumps instead of the gasoline-engine-driven, 3-kW portable generator, which is a standard component of a field laundry set. Rigid tanks and piping were substituted for collapsible tanks and hoses. None of these substitutions adversely affected treatment system operations or test program results.

Test Equipment Description and Functions

The following sections describe the equipment used for the tests, excluding pipes, fittings, and pumps.

Fresh Water Tank (FWT)

The FWT was a 500-gal-capacity cylindrical metal tank without a cover. The tank was used to temporarily store water used for laundering clothes. The first 500 gal of fresh water and subsequent makeup water were obtained from the municipal water line in the laboratory. This tank held treated wastewater before it was recycled for washing subsequent loads of clothing (Figures 1 and 2).

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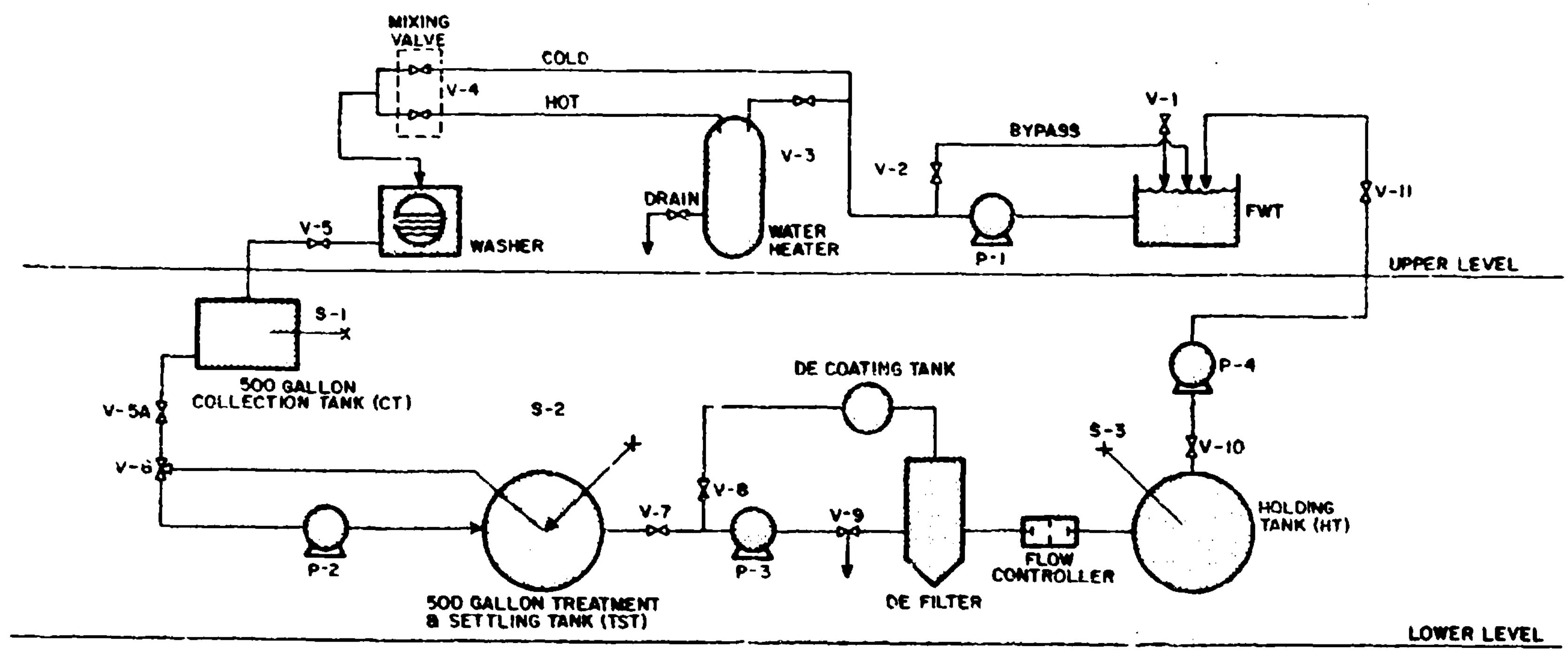
[2] J. M. Morgan et al., *Mathematical Modeling for Evaluation of Field Water Supply Alternatives (Arid and Semi-Arid Regions)* (VMI Research Laboratory, January 1981).



VALVES

V-1 FWT CHARGE
V-2 WASHER FEEDWATER BYPASS
V-3 HEATER FEED
V-4 HOT/COLD WATER MIX
V-5 WASHER DISCHARGE (INTEGRAL)
V-5A WASTEWATER TRANSFER
V-6 RECIRCULATION/TRANSFER THREE-WAY
V-7 TST THREE-WAY
V-8 DE COATING TANK
V-9 FILTRATION/WASTE
V-10 HOLDING TANK
V-11 FWT/RECYCLE FEED

SAMPLING POINTS x

S-1 COLLECTION TANK
S-2 TREATMENT/SETTLING TANK
S-3 HOLDING TANK

PUMPS

P-1 FEEDWATER
P-2 TRANSFER/RECIRCULATION
P-3 DE FILTER
P-4 FWT/RECYCLE/TRANFER

Figure 1. Test setup.

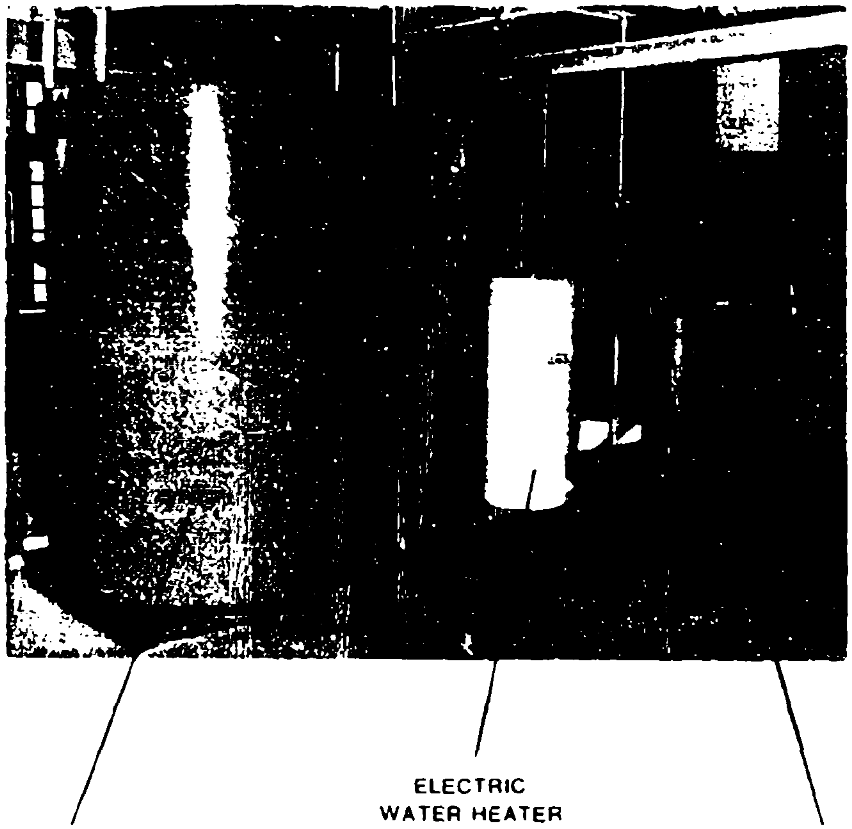


Figure 2. Arrangement of washing machine, water heater, and freshwater tank in the test shop.

Water Heater

The electric, 4500-W water heater was a Southern States glass-lined heater with a 42-gal capacity. Stored washwater from the FWT was pumped through the heater to the washing machine at 160°F (Figures 1 and 2).

Washing Machine

A single front-loading commercial/industrial-type front-loading washer/extractor of 70-lb capacity was used (Figures 1 and 2). The washing machine discharged both washwater and rinsewater into a collection tank (CT) by gravity through a pipe discharge line. The FWT, electric water heater, and washing were located on an upper laboratory level about 15 ft above the lower level where the remaining equipment was located (see Figures 1 and 2).

Collection Tank (CT)

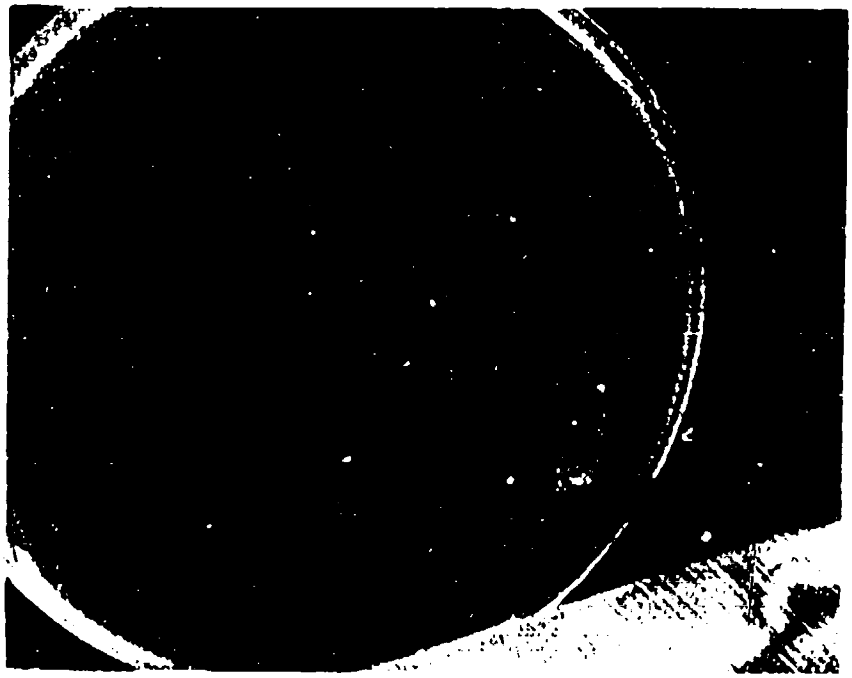
The CT--a graduated 500-gal-capacity polyethylene cylindrical tank without a cover--was used to collect wash- and rinse-cycle wastewater before treatment (Figures 1 and 3).

Treatment and Settling Tank (TST)

The TST was a GFE 500-gal collapsible fabric tank complete with staves, pegs, spreaders, and ground cloth. Wastewater collected in the collection tank was pumped to the TST, where the polymers and powdered activated carbon were added and mixed. Flocculation and settling--the first step of the treatment process--occurred here (Figures 1 and 4).

Diatomaceous Earth Precoat Tank (DE Precoat Tank)

The DE Precoat Tank was a 5-gal-capacity graduated polyethylene cylindrical tank without a cover (Figures 1 and 4). This tank was used to prepare a diatomite slurry needed to precoat the septums in the diatomaceous earth filter.



COLLECTION TANK (CT)

Figure 3. Laundry wastewater collection tank used in the test setup.

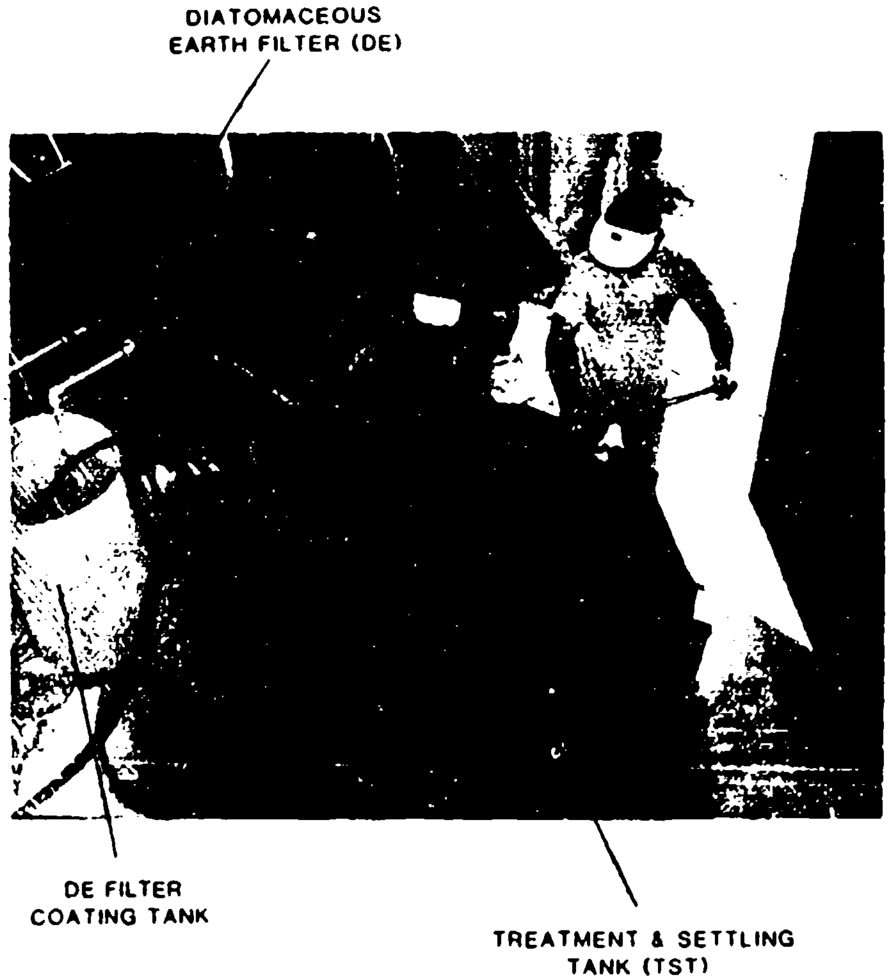


Figure 4. Laundry wastewater treatment units used in the test setup.

Diatomaceous Earth Filter (DE Filter)

The 420-gph DE filter was part of the 420-gph Water Purification Set (ERDLATER). It was equipped with an integral 110-V, electrically driven pump and provided the second step in the treatment process (Figures 1 and 4).

Holding Tank (HT)

The HT was a 250-gal-capacity graduated polyethylene cylindrical tank without a cover. It was used to collect the filtered water produced by the DE filter. Calcium hypochlorite is added manually to disinfect the water for reuse in subsequent washing operations.

Clothes Washing Operations

The front-loading washing machine was hand-loaded with about 60 lb of soiled, standard Army-issue fatigues and miscellaneous items such as underwear and bed linen. The clothes were soiled manually since the same 60-lb load of fatigue uniforms was reused for each wash cycle. Finely graded dirt was transferred to the clothing by dragging each uniform lightly across a container filled with dirt. Also, 50 mL of unused engine oil was poured randomly onto the clothing before each load was placed in the washer. Two ounces of detergent were placed in the washer detergent box, valve V-4* was turned to the hot/cold position, and the washer was started. With pump P-1 operating, a 5-minute washing period was begun. Upon completion of the washing period, valve V-4 was closed, pump P-1 was turned off, and the washer was drained for 5 minutes. One ounce of detergent was placed in the detergent box, and the 10-minute procedure was repeated. After the second wash and extraction period, valve V-4 was turned to the hot/cold mix position, pump P-1 was turned on, and the washload was rinsed for 2 minutes. Valve V-4 was closed, pump P-1 was turned off, and the washer was drained for 5 minutes. After complete extraction, this 7-minute procedure was repeated. The wastewater effluent flowed by gravity into the CT when valve V-5A was opened. These procedures for washing one load of clothes comprised one wash cycle. About 13 wash cycles were needed to fill the CT with a single 500-gal batch of laundry wastewater.

After the CT was filled to the 500-gal level, the wastewater was mixed vigorously with a paddle; 16 samples in 50-mL biochemical oxygen demand (BOD) bottles were then taken. The samples were divided into fractions for replicate testing of chemical and physical constituents.

Wastewater Treatment Operations

After each washing cycle and prior to treatment, jar tests were performed to determine the amount of powdered carbon to be added to the wastewater. (Activated carbon adsorbs organic substances. The polymers cause colloidal particles to clump and settle to the bottom of the tank.) However, the validity of these tests was questionable because of the difficulty in measuring the small amounts of Type I and II Polymer that also had to be added to each sample.

Upon completion of water transfer from CT to TST, powdered HYDRODARCO activated carbon was added to the TST. By closing valve V-5A and operating pump P-2, the wastewater was recirculated for 20 minutes to mix it thoroughly. After the powdered activated carbon was mixed, 75 mL of Type I Polymer (CAT-FLOC) was diluted with 750 mL of fresh water, half of which was added to 1 gal of TST water to provide a polymer solution; the polymer solution was then added to the TST. This step was repeated for the remaining Type I Polymer solution. The contents of the tank were stirred with a paddle at 3- to 5-minute intervals for the next 30 minutes.

During this time interval, two 1000-mL beakers were filled with fresh water; 1/2 g of Type II Polymer was added to each beaker (sprinkled to avoid clumping) and frequently agitated to mix the polymer thoroughly. The Type II Polymer solution was then added to the TST and the contents of the tank stirred with a paddle for about 5 minutes, or until large floc appeared. The contents of the TST were allowed to settle for 20 minutes.

*The valves and pumps described in this section are shown in Figure 1.

Then, 16 water samples were taken from the TST using 500-mL BOD bottles and divided into fractions for analysis.

The next step of the treatment process involved adding 0.8 lb of diatomite as precoat on the DE filter and filtering the supernatant in the TST. The DE slurry was then pumped into the DE filter using pump P-3 which is integral to the filter. This procedure required valve V-7 to be closed and valve V-8 to be open. The slurry was recirculated for about 5 minutes to fully coat the septums in the DE filter. Valves were then reset (V-7 to open, V-8 to close, and the three-way valve on the DE filter to filter). To avoid pumping the sludge in the bottom of the TST, a 90-degree elbow was attached to the end of the 1-1/2-in. tank discharge line, and the decrease in the tank's water level was observed to avoid overpumping.

The filtered discharge from the DE filter was collected in the 500-gal HT. After 200 to 300 gal were filtered, two samples were collected in 500-mL BOD bottles for chemical analysis and 500-mL samples were taken for turbidity analysis after about 400 gal were filtered. At the midpoint of the filtering process, a 4-oz sample of filtrate was collected in a NASCO sodium thiosulfate Whirl-Pak bag for testing total organic carbon (TOC) and fecal coliform levels.

Recycling Procedure

The treatment process outlined above describes a typical cycle in the treatment of 500 gal or a "batch" of laundry wastewater. Table 1 summarizes the details of the treatment given each recyling sequence within a batch.

Data reported in Table 1 cover only Batches 4, 5, and 6, each of which varied in the number of cycles conducted. Batches 1, 2, and 3 were used to establish the test protocol, debug the test facility, and train the operators; consequently, no meaningful data were developed from them.

Several adjustments were made to the basic operating procedure during the testing to improve the treatment procedure's efficiency. These adjustments are reflected in Table 1 and are discussed below.

Batch 4 treatment was begun (cycle 1) by adding soda ash in accordance with instructions accompanying the Laundry Wastewater Pollution Abatement Kit. However, jar tests revealed floc would not form using Types I and II Polymer because of high alkalinity. Therefore, 500 mL of acid were added to lower the wasterwater's pH. The optimum pH level for floc formation was between 6.5 and 7.5. It was determined that 100 mL of acid had to be added before subsequent treatment cycles to adjust the pH to the required range.

The number of times that the DE filter had to be backwashed varied due to difficulties in filtering the supernatant in the TST. The DE filter pump's suction line was attached to the side of the TST near the base of the tank. Settled solids were carried over into the DE filter, causing it to clog quickly. This condition was corrected when a 90-degree elbow was installed on the end of the suction line to raise the intake above the deposited solids level. The same filter clogging was observed when insufficient time was allowed for optimum settlement to occur. This problem was reduced as the operators became more aware of sludge pickup by the filter pump. A noticeable reduction in the number of backwashes occurred as the testing progressed through Batch 5 and into Batch 6.

Table 1

Record of Chemicals Used To Treat Laundry Wastewater
(Cycles Per Batch)

Batch No.	4			5								6					
Cycle No.	1	2	3	1	2	3	4	5	6	7	8	1	2	3	4	5	6
ITEM																	
Washwater, Initial (gal)	500	-	-	500	-	-	-	-	-	-	-	500	-	-	-	-	-
Freshwater Makeup (gal)	-	97	50	-	188	0	50	75	23	55	50	-	107	25	60	15	8
Acid Added (mL)	500	100	100	100	100	100	100	100	100	100	250	100	100	100	100	100	100
Polymer Type I Added (mL)	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75	75
Polymer Type II Added (g)	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Carbon Added (lb)	6.5	0	0	6.5	6.5	6.5	6.5	6.5	6.5	6.5	6.5	6.5	6.5	4.0	2.0	0	0
Diatomaceous Earth (lb)	0.8	1.0	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8
No. of Filter Backwashes*	-	4	1	4	5	3	3	3	4	1	1	8	2	1	1	1	2

*DE filter backwashed whenever differential pressure reached 45 psi.

To obtain the most cost-effective use of chemicals, the amount of powdered carbon used during Batch 6 was reduced. The effects of this effort are reflected in the data for cycles 3 through 6.

Sampling and Analysis

The interim water quality criteria prescribed for recycled laundry water by the OTSG cover only the four parameters listed in Table 2. These and other parameters were evaluated for this test program to identify the most common chemical constituents of each.

During each cycle, test samples were taken for complete analysis from both the raw laundry wastewater and filtrate to determine the effectiveness of the treatment process. The following tests were made using the standard procedures as described:

1. Alkalinity: methyl orange indicator method.

2. Total Dissolved Solids (TDS): weight of the amount of oven-dried residue.

3. Calcium Hardness: a calcium indicator and potassium hydroxide, with Hach's HexaVer solution as titrant.

4. Linear Alkyl Sulfates (LAS): crystal violet method, along with the Hach DR 3 meter.

5. Total Phosphate: persulfate digestion method.

6. Orthophosphate: amino acid method.

Table 2

Interim Water Quality Standard for Direct Reuse of Laundry Wastewater*

Parameter	Limits
pH	6.5 to 7.5
Turbidity	<1 turbidity unit desirable <5 turbidity units permissible
Free Available Chlorine	5 mg/L $> 20^{\circ}C$ 10 mg/L $< 20^{\circ}C$
Soap Hardness	Adequate detergency

*Source: Department of the Army, Office of the Surgeon General.

7. Total Organic Carbon (TOC): Beckman Total Organic Carbon Analyzer, Model 915.

8. Sulfate: turbidimetric method using the Hach SulfaVer 4 Sulfate Reagent.

9. Turbidity: Hach Laboratory Turbidimeter.

10. pH: Photovolt pH meter. (The meter was standardized several times each work day with pH buffer).

11. Total Hardness: EDTA titrimetric method, using Eriochrome Black T as indicator, Hach Standard HexaVer as titrant, and ammonium hydroxide solution as buffer.

3 RESULTS OF THE BATCH OPERATIONS

Six batch runs were made during the test program, with each batch subjected to a different number of reuse cycles. Batches 1, 2, and 3 were trial runs used to provide experience with the experimental setup and familiarize project personnel with the equipment and procedures. Data obtained from batch runs 4, 5, and 6 were used to analyze the wastewater recycling system's effectiveness.

Tables 3, 4, and 5 provide the results of batch runs 4, 5, and 6, respectively. The tables present characteristics of washer effluent and of settled and filtered laundry wastewater during various reuse cycles. The results represent mean values of up to four replicate analyses for each parameter.

Figures 5 through 13 and 15 through 23 present the variations in mean concentrations of water quality parameters during batch runs 5 and 6, respectively. These figures compare the variation of wastewater effluent and settled water quality parameters during the reuse cycles. Figures 14 and 24 show variations of mean turbidity of filtered water, compared to the washer effluent and settled water for batch runs 5 and 6, respectively.

Figure 25 gives the percentage of occurrences when there was a significant difference ($p < 0.01$) between the means of measured parameters in the laundry effluent and settled waters. The information provided identifies (1) when the parameter measured in the effluent exceeded that measured in the settled water for a given cycle, (2) when the parameter measured in the settled water exceeded that in the effluent, and (3) when there was no significant difference between the two parameters.

Table 3

Characteristics of Washer Effluent and of Settled and Filtered Laundry Wastewater During Various Reuse Cycles of Batch Run 4

Sample		pH	Turbidity (NTU)*	TDS (ppm)	Alkalinity (ppm)	Calcium (ppm)	Sulfate (ppm)	Phosphate (ppm) Total	Phosphate (ppm) Ortho	LAS (ppm)
			Mean Concentration of Parameters							
Washer Effluent										
Cycle	#1	6.80	752	673	270	67	37	88	6.6	0.13
	#2	8.55	409	1493	517	70	70	136	16.3	0.40
	#3	7.38	452	1640	625	70	76	80	20.5	0.18
Settled										
Cycle	#1	7.00	12.5	1478	509	84	430	47	7.6	0.11
	#2	7.10	108	1376	444	73	363	141	15.0	0.61
	#6	7.55			412	76	64	67	14.4	0.78
Filtered										
Cycle	#1		4.15							
	#2		13.9							
	#3		45.7							

*Nessler Turbidity Unit

Table 4

**Thermal Energy Storage Modules
Using Phase Change Materials**

Sample		pH	Turbidity (NTU)	TDS (ppm)	Alkalinity (ppm)	Calcium (ppm)	Sulfate (ppm)	Phosphate (ppm) Total	Phosphate (ppm) Ortho	LAS (ppm)	TOC (ppm)
						Mean Concentration of Parameters					
Washer Effluent Cycle	#1	8.70	154	750	420	49	142	128	11.5	0.31	64.5
	#2	8.70	699	1838	430	80	170	175	13.2	0.13	81.5
	#3	9.10	631	1835	447	73	269	184	20.5	0.19	78.0
	#4	8.90	1555	2439	570	80	413	209	31.8	0.14	80.0
	#5	8.90	938	2547	644	136	580	339	71.0	0.11	63.0
	#6	8.80	791	2276	655	56	343	298	30.3	0.16	62.0
	#7	9.10	759	2510	624	73	635	423	59.0	0.20	87.0
	#8	8.80	711	2611	708	72	850	380	58.0	0.25	63.0
Settled Cycle	#1	7.10	28.5	767	336	66	178	93.5	11.5	0.30	12.0
	#2	7.30	47.0	1006	361	80	249	64.0	15.8	0.13	1.8
	#3	7.70	15.3	1194	513	42	403	144	19.7	0.11	0.5
	#4	7.50	27.3	1509	429	39	450	214	36.5	0.15	1.5
	#5	7.70	33.0	1695	476	76	619	160	54.0	0.19	0.1
	#6	7.70	18.0	1795	440	79	142	250	52.3	0.27	0.5
	#7	8.00	15.7	2036	496	66	670	344	62.5	0.29	2.3
	#8	7.20	12.0	2350	474	57	883	421	75.3	0.13	0.1
Filtered Cycle	#1		4.88								
	#2		10.9								
	#3		1.40								
	#4		1.48								
	#5		2.00								
	#6		1.40								
	#7		0.61								
	#8		2.08								

Table 5

Characteristics of Effluent, Settled and Filtered Laundry Wastewater During Various Reuse Cycles of Batch Run 6

Sample		pH	Turbidity (NTU)	TDS (ppm)	Alkalinity (ppm)	Calcium (ppm)	Sulfate (ppm)	Phosphate (ppm) Total	Phosphate (ppm) Ortho	LAS (ppm)	TOC (ppm)
		Mean Concentration of Parameters									
Washer Effluent											
Cycle	#1	8.80	579	1236	416	60	117	157	16.5	0.19	63.0
	#2	8.90	1580	1600	474	68	216	152	20.0	0.19	82.0
	#3	9.00	1965	1722	550	96	318	175	27.8	0.14	88.8
	#4	9.10	1697	2472	656	110	345	218	31.0	0.26	83.0
	#5	8.60	1314	2542	605	117	355	284	37.0	0.14	80.0
	#6	8.50	685	2745	653	112	673	432	61.3	0.23	
Settled											
Cycle	#1	7.00	65	934	275	55	209	129	17.9	0.69	18.8
	#2	7.40	8.0	1018	363	71	318	210	21.3	0.20	0.10
	#3	7.30	6.0	1267	404	80	305	229	24.5	0.20	0.80
	#4	7.60	9.2	1585	471	78	453	225	45.3	0.28	0.30
	#5	7.10	27.0	1700	495	77	487	308	55.5	0.43	7.30
	#6	7.00	99.0	2055	526	80	112	424	69.3	0.36	
Filtered											
Cycle	#1		9.95								
	#2		1.04								
	#3		0.84								
	#4		0.75								
	#5		7.38								
	#6		27.0								

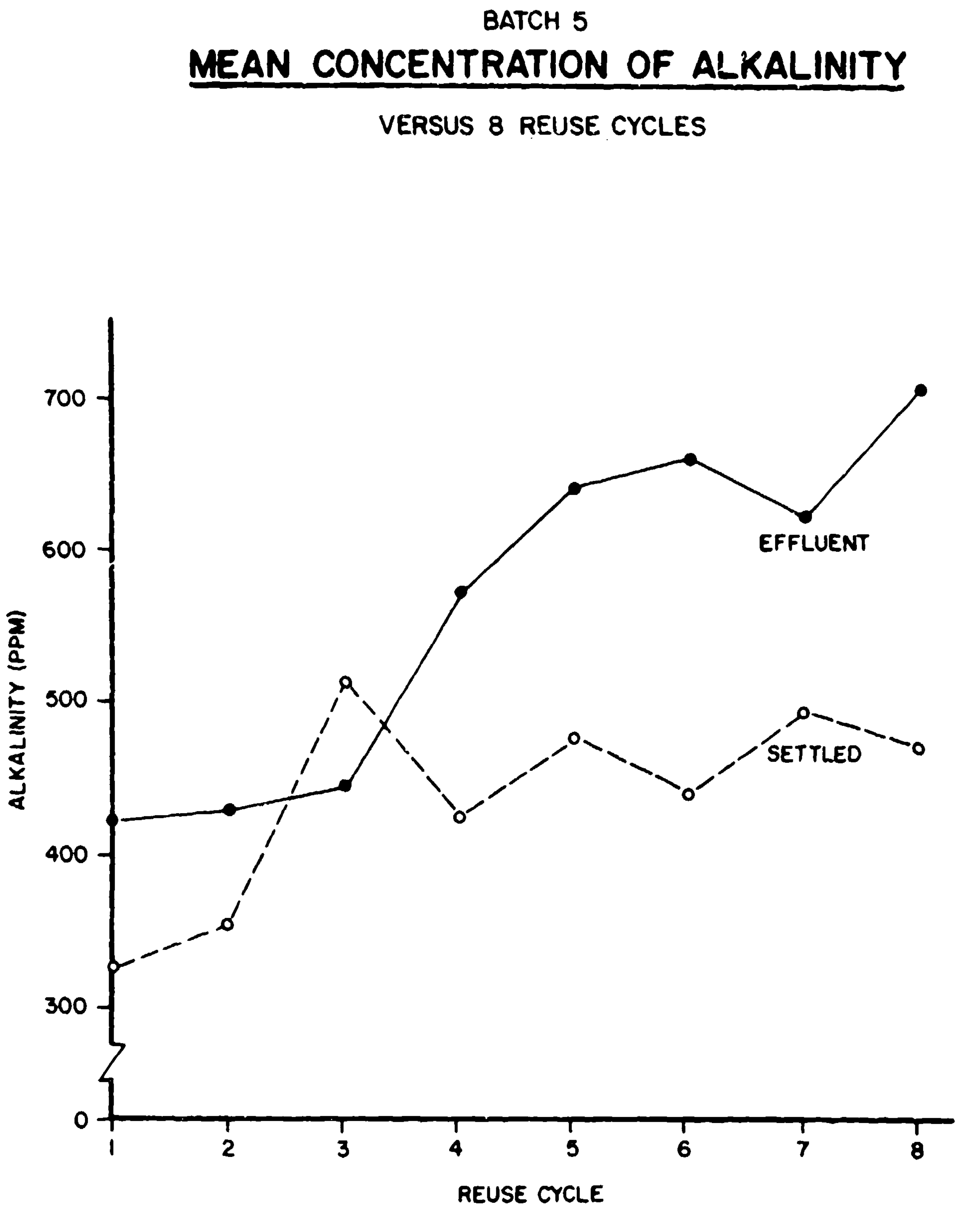


Figure 5. Comparison of mean alkalinity concentration in washer effluent and treated settled waters during various reuse cycles of batch run 5.

BATCH 5

MEAN CONCENTRATION OF TOTAL DISSOLVED SOLIDS

VERSUS 8 REUSE CYCLES

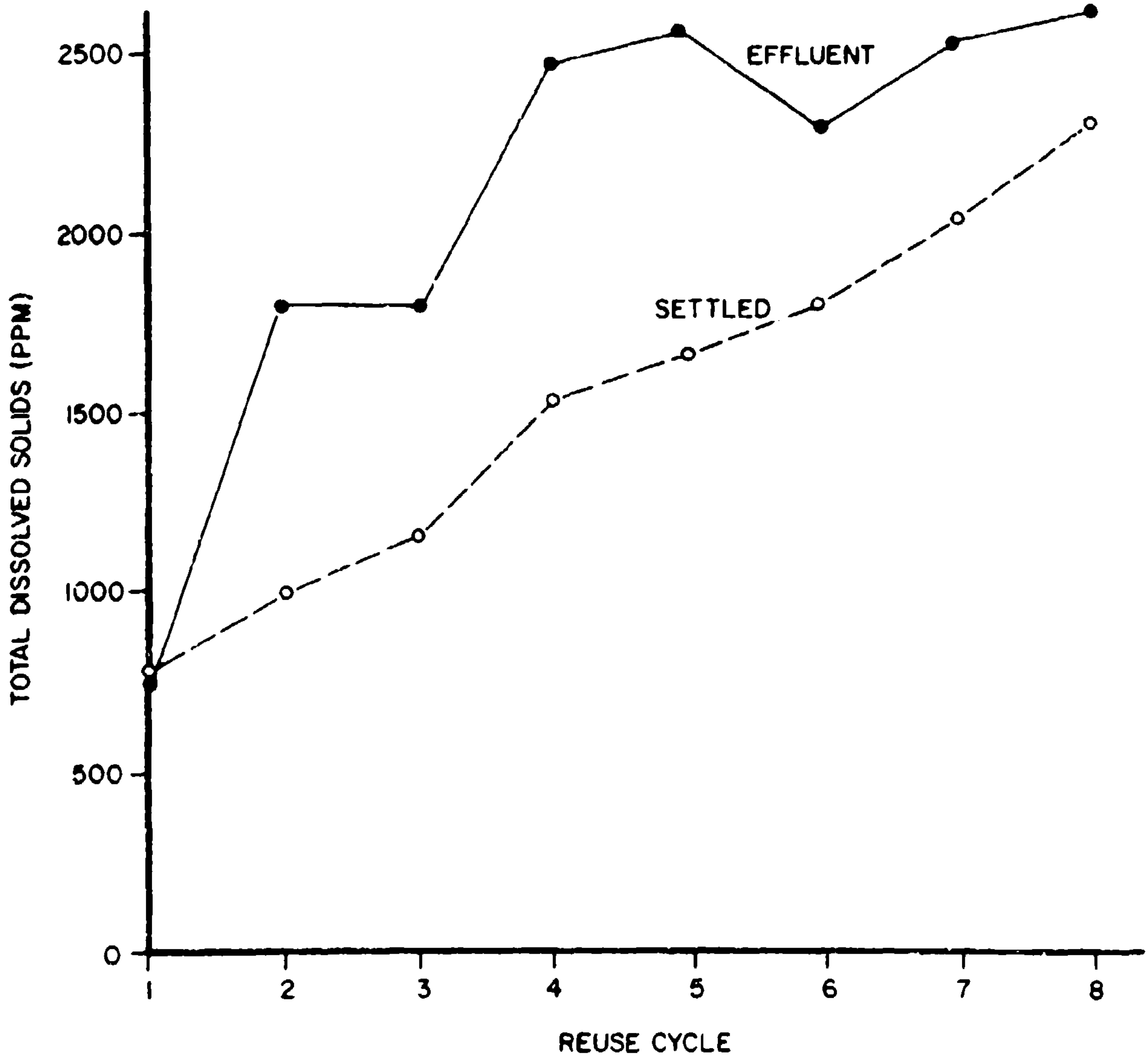


Figure 6. Comparison of mean total dissolved solids concentration in washer effluent and treated settled waters during various reuse cycles of batch run 5.

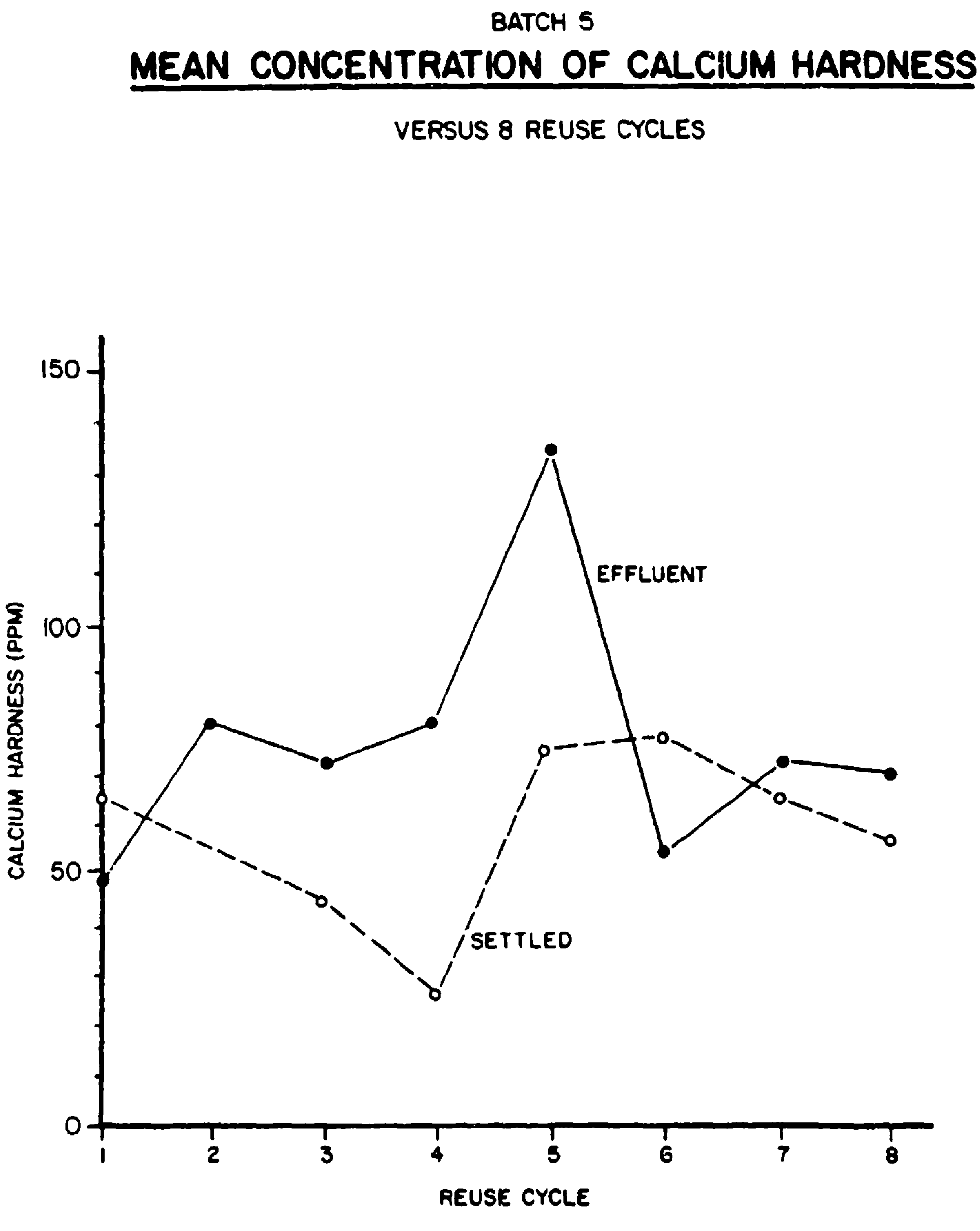


Figure 7. Comparison of mean calcium hardness concentration in washer effluent and treated settled waters during various reuse cycles of batch run 5.

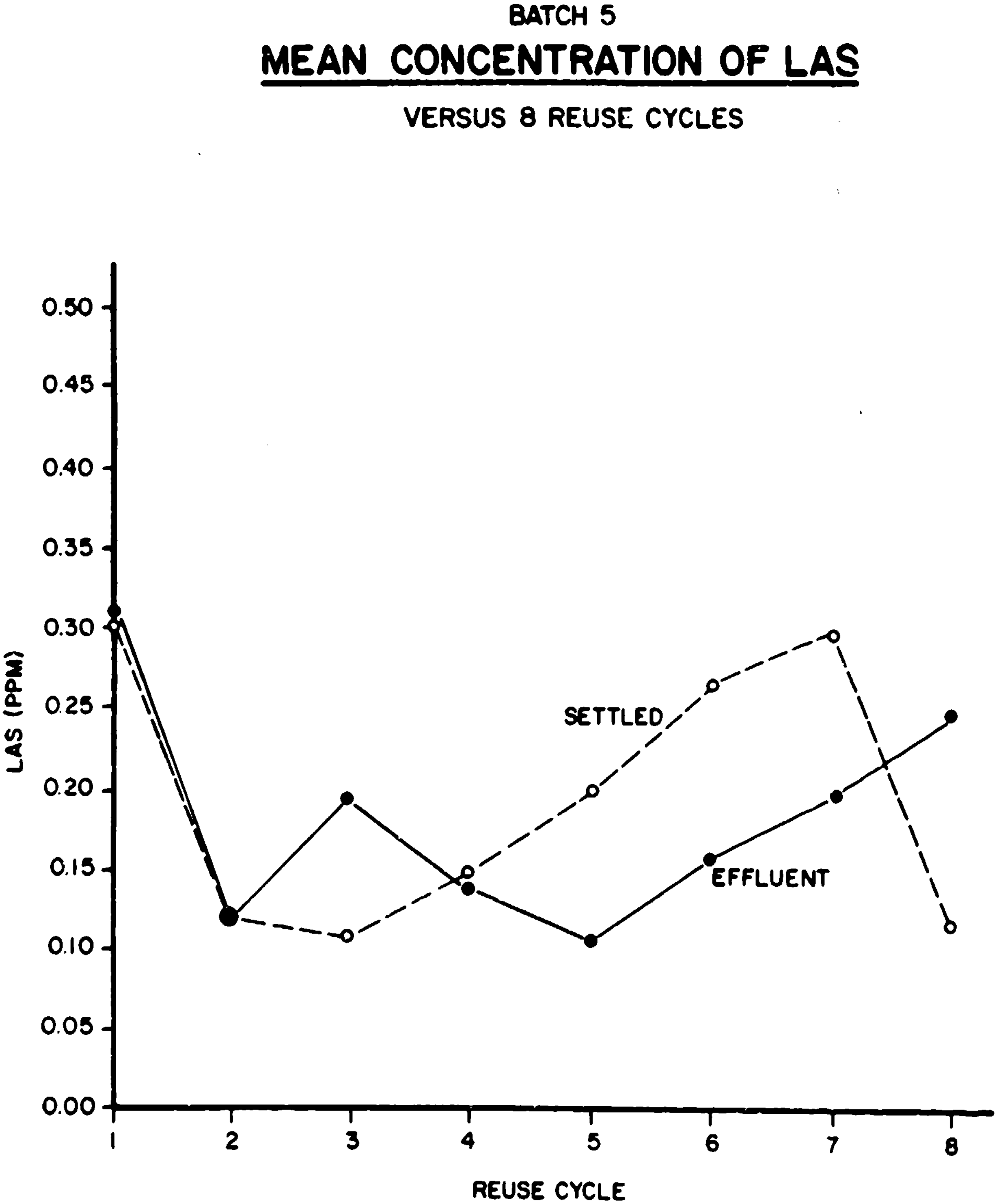


Figure 8. Comparison of mean LAS concentration in washer effluent and treated settled waters during various reuse cycles of batch run 5.

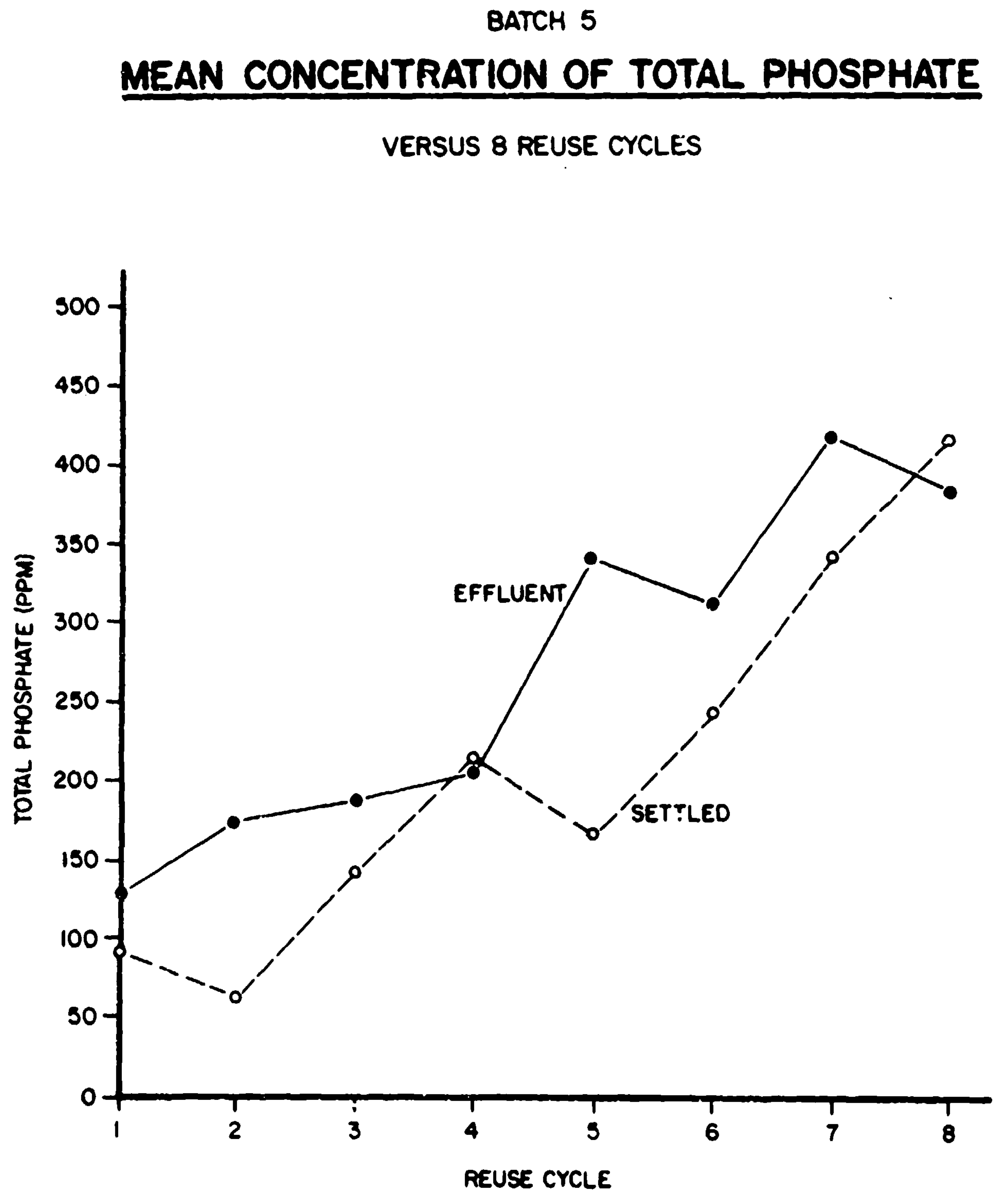


Figure 9. Comparison of mean total phosphate concentration in washer effluent and treated settled waters during various reuse cycles of batch run 5.

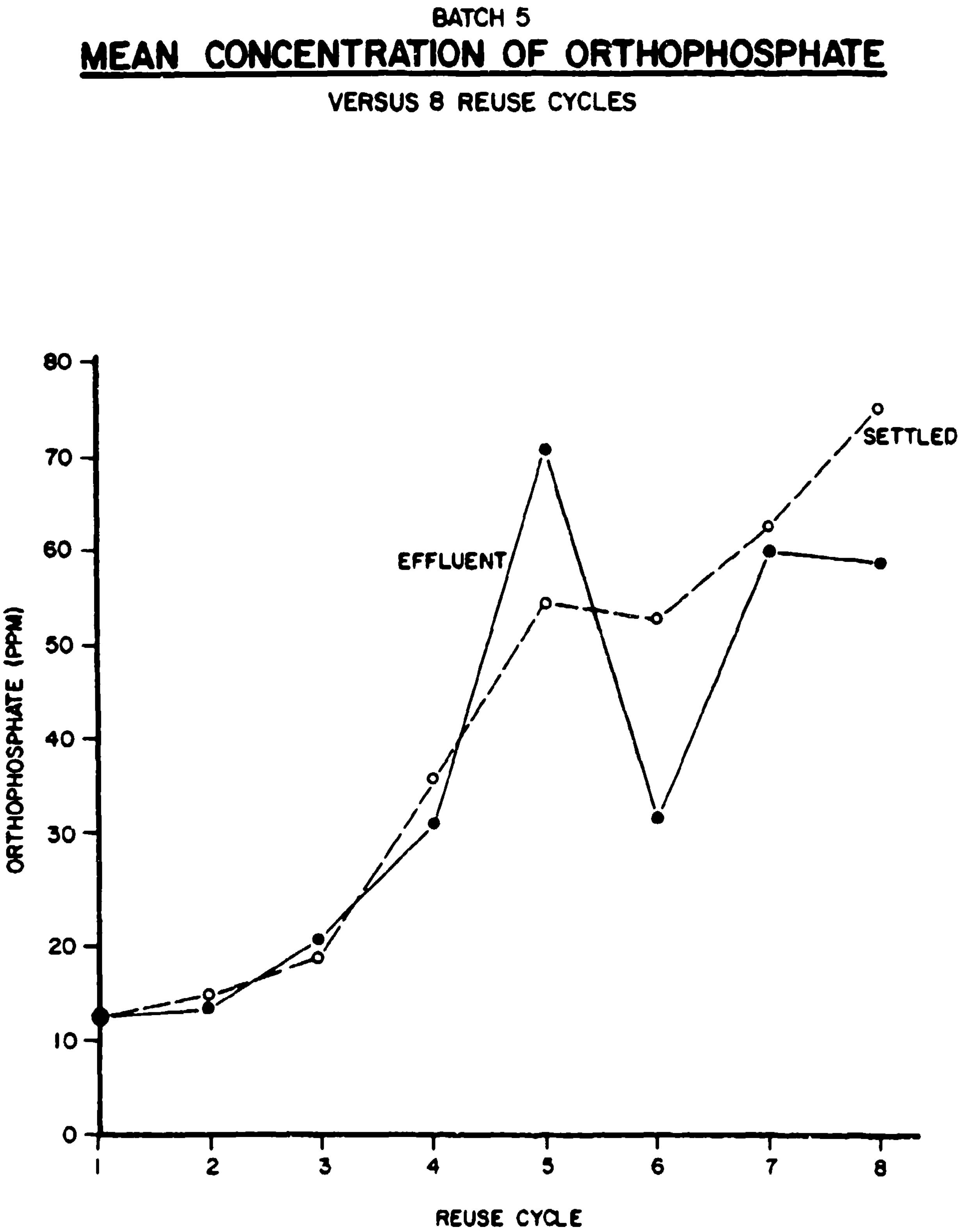


Figure 10. Comparison of mean orthophosphate concentration in washer effluent and treated settled waters during various reuse cycles of batch run 5.

BATCH 5

MEAN CONCENTRATION OF TOTAL ORGANIC CARBON

VERSUS 8 REUSE CYCLES

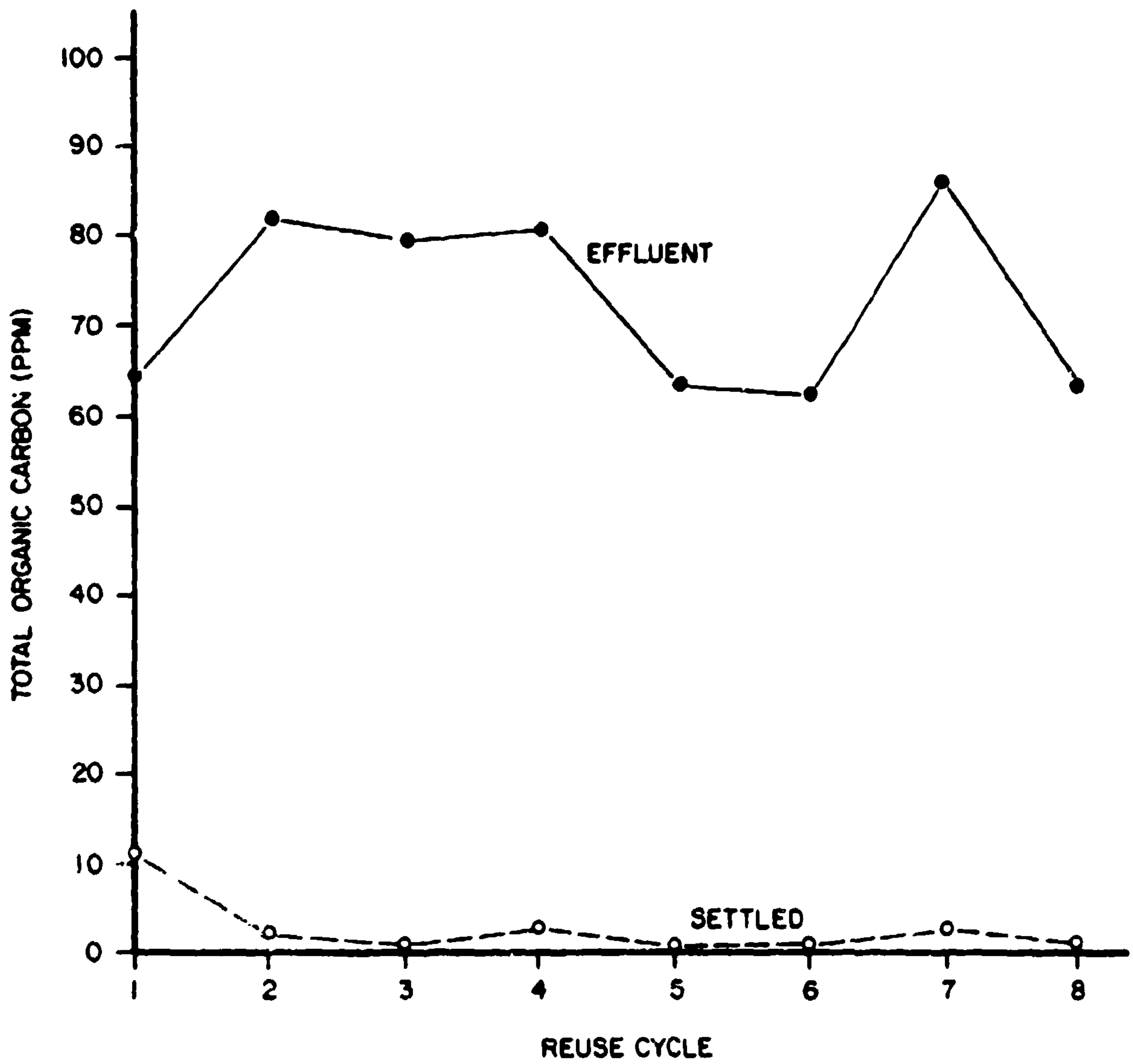


Figure 11. Comparison of mean TOC concentration in washer effluent and treated settled waters during various reuse cycles of batch run 5.

BATCH 5

MEAN CONCENTRATION OF SULFATE

VERSUS 8 REUSE CYCLES

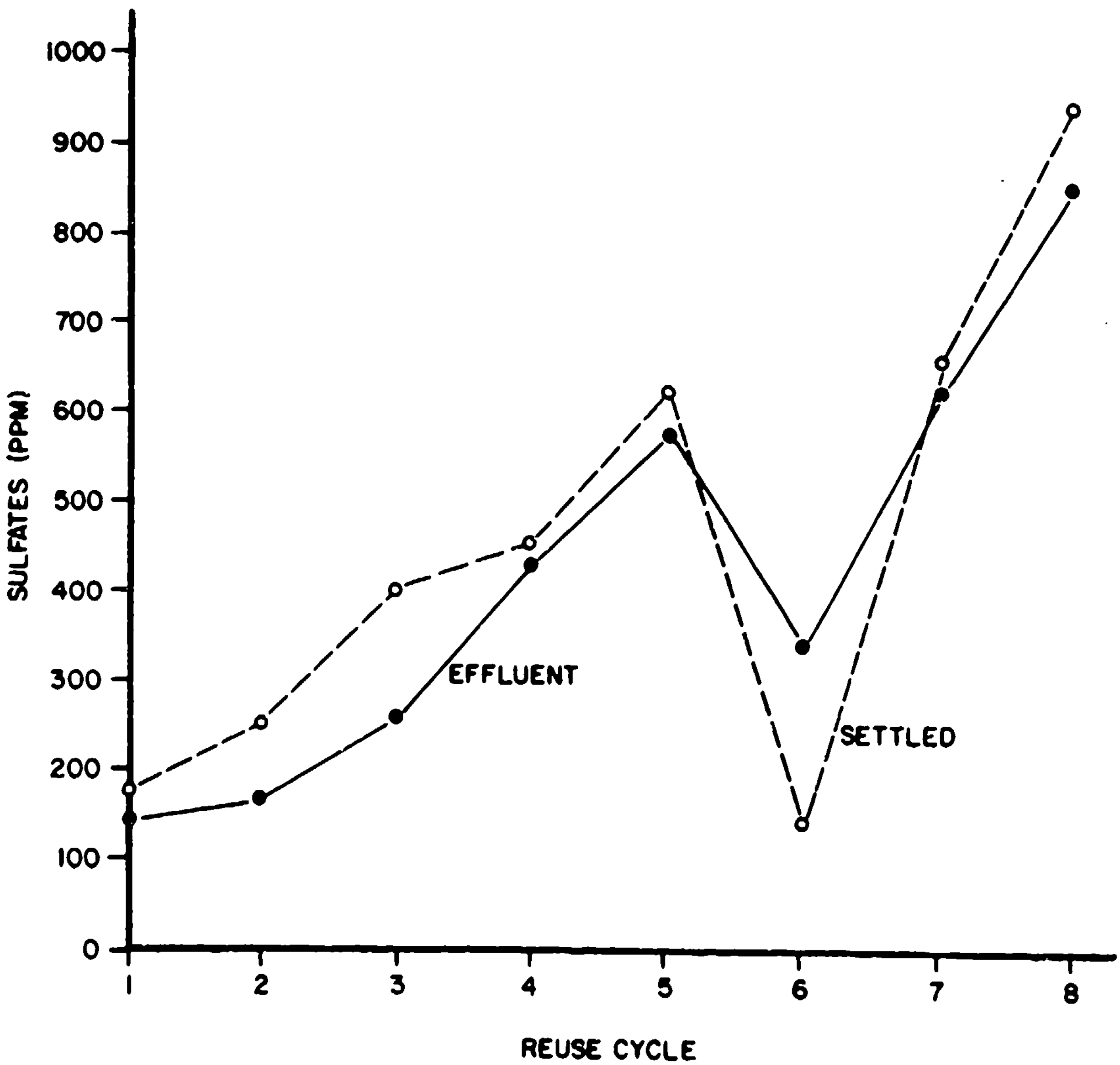


Figure 12. Comparison of mean sulfate concentration in washer effluent and treated settled waters during various reuse cycles of batch run 5.

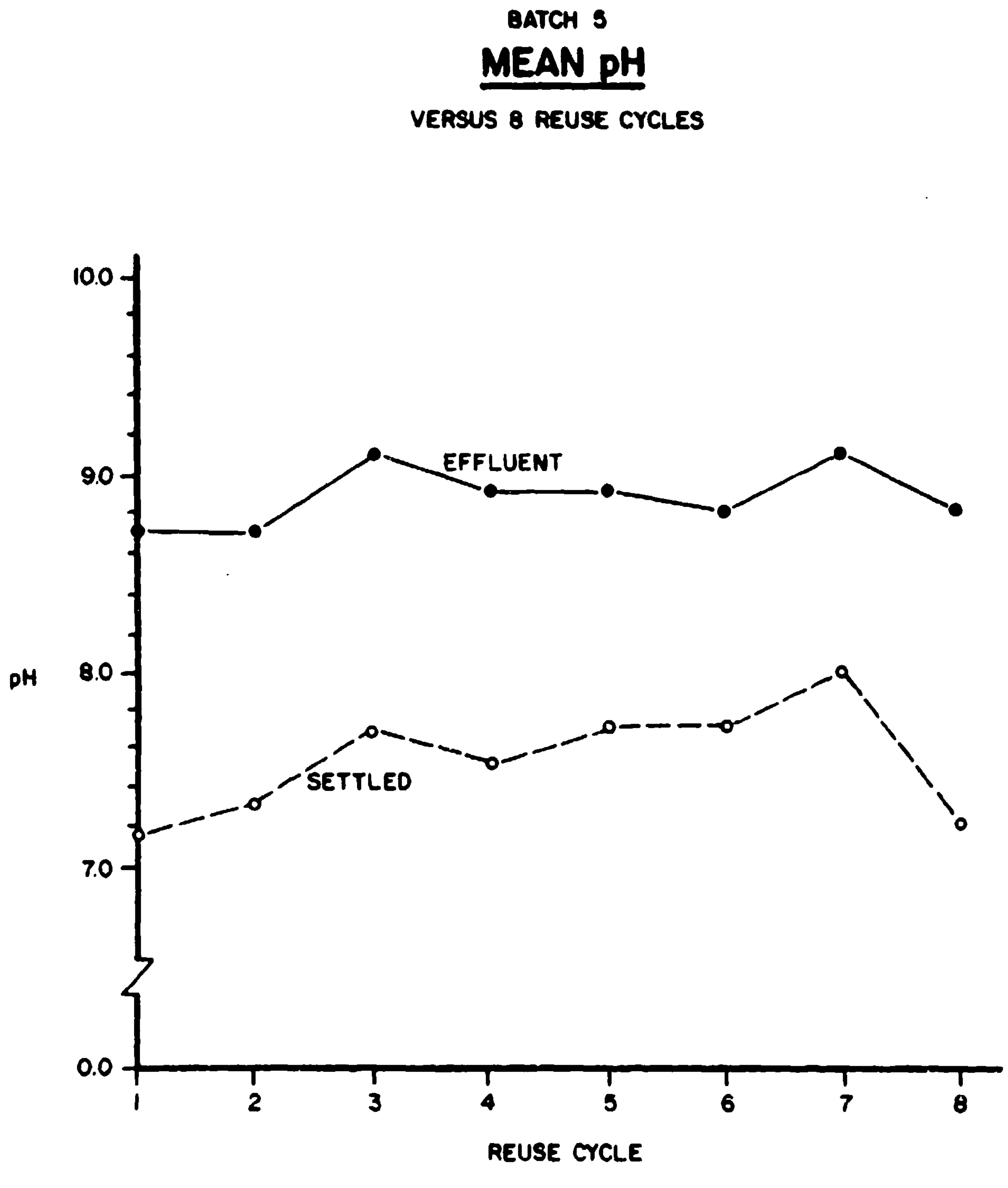


Figure 13. Comparison of mean pH in washer effluent and treated settled waters during various reuse cycles of batch run 5.

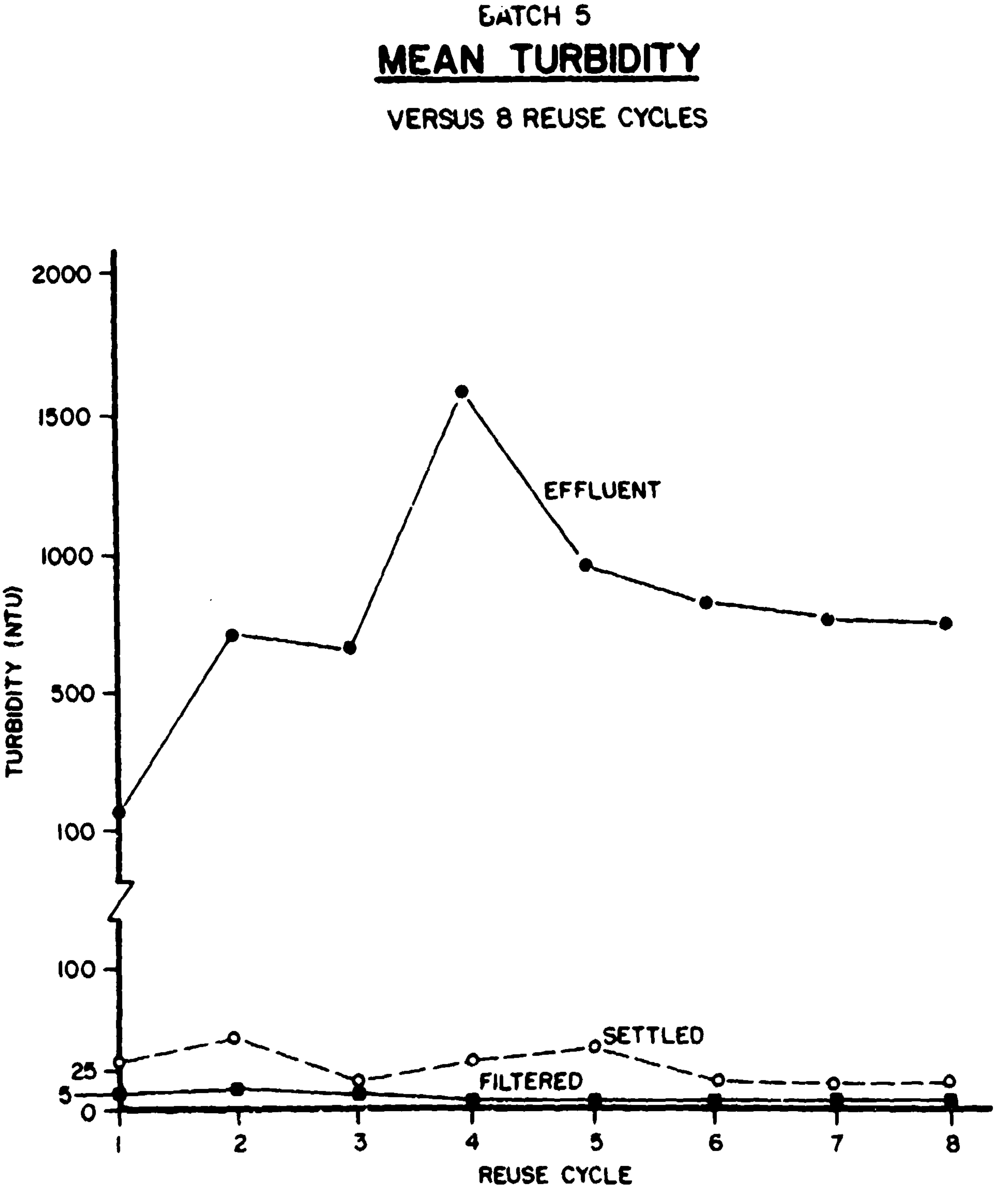


Figure 14. Comparison of mean turbidity in washer effluent and treated settled and filtered waters during various reuse cycles of batch run 5.

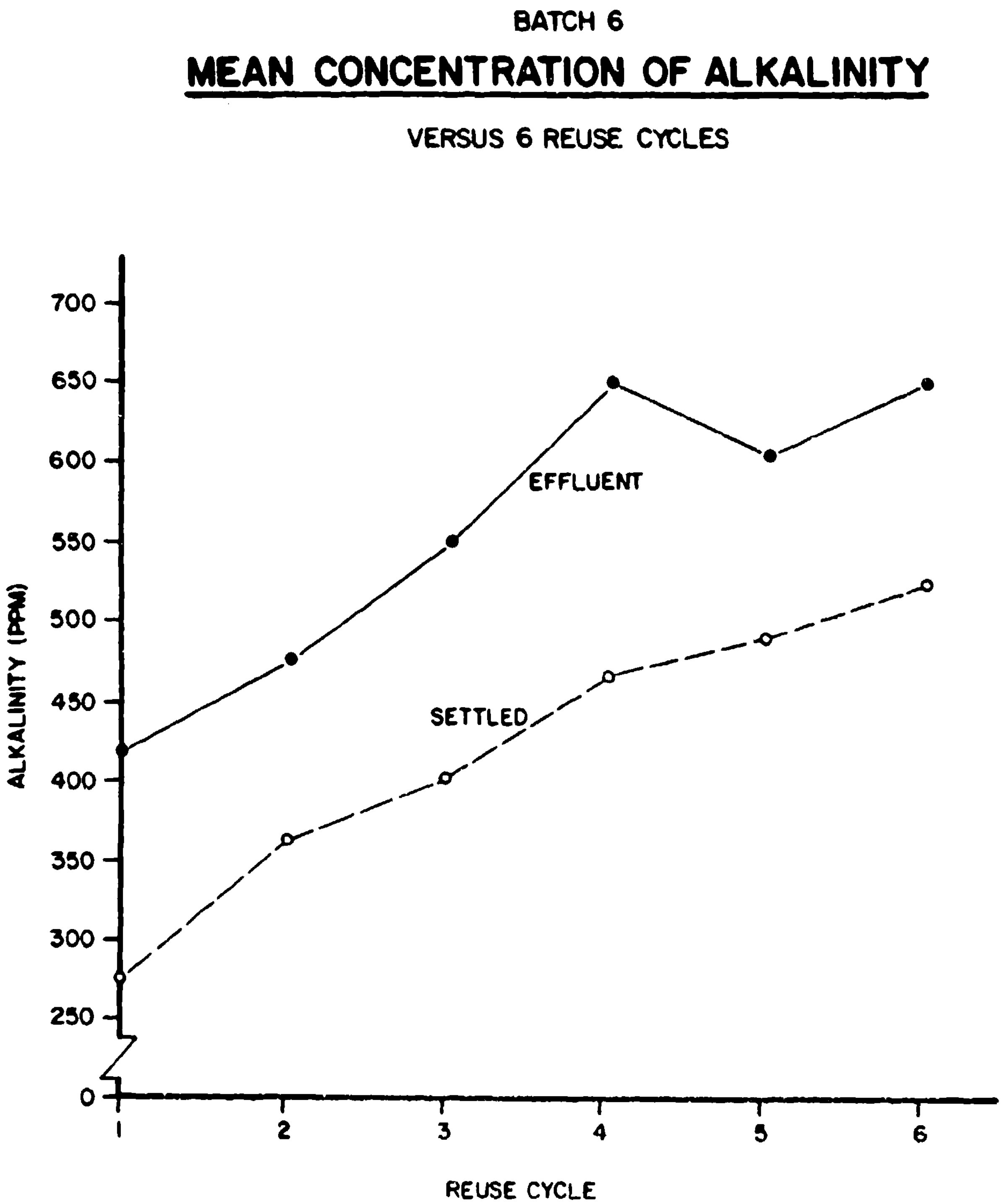


Figure 15. Comparison of mean alkalinity concentration in washer effluent and treated settled waters during various reuse cycles of batch run 6.

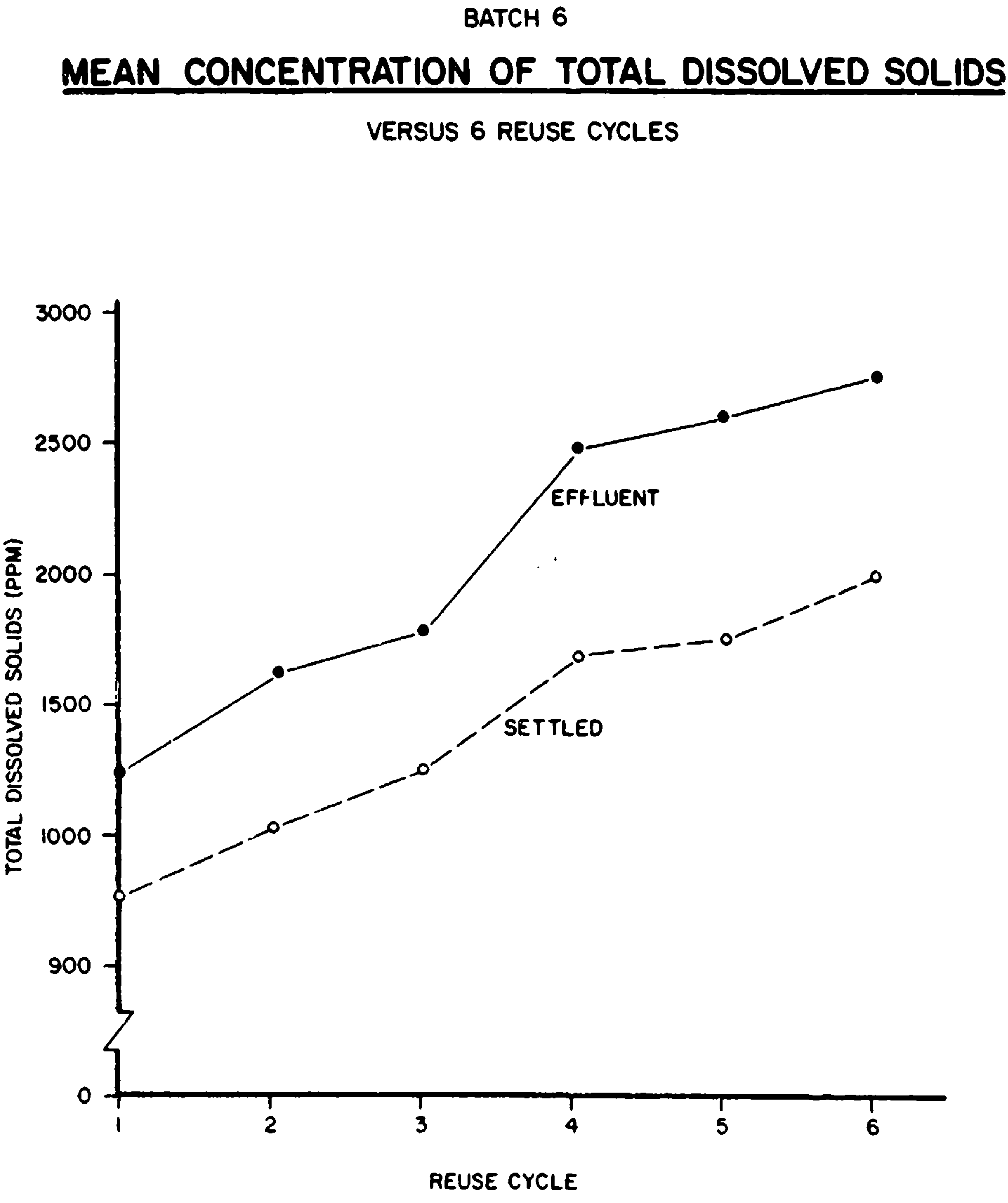


Figure 16. Comparison of mean total dissolved solids concentration in washer effluent and treated settled waters during various reuse cycles of batch run 6.

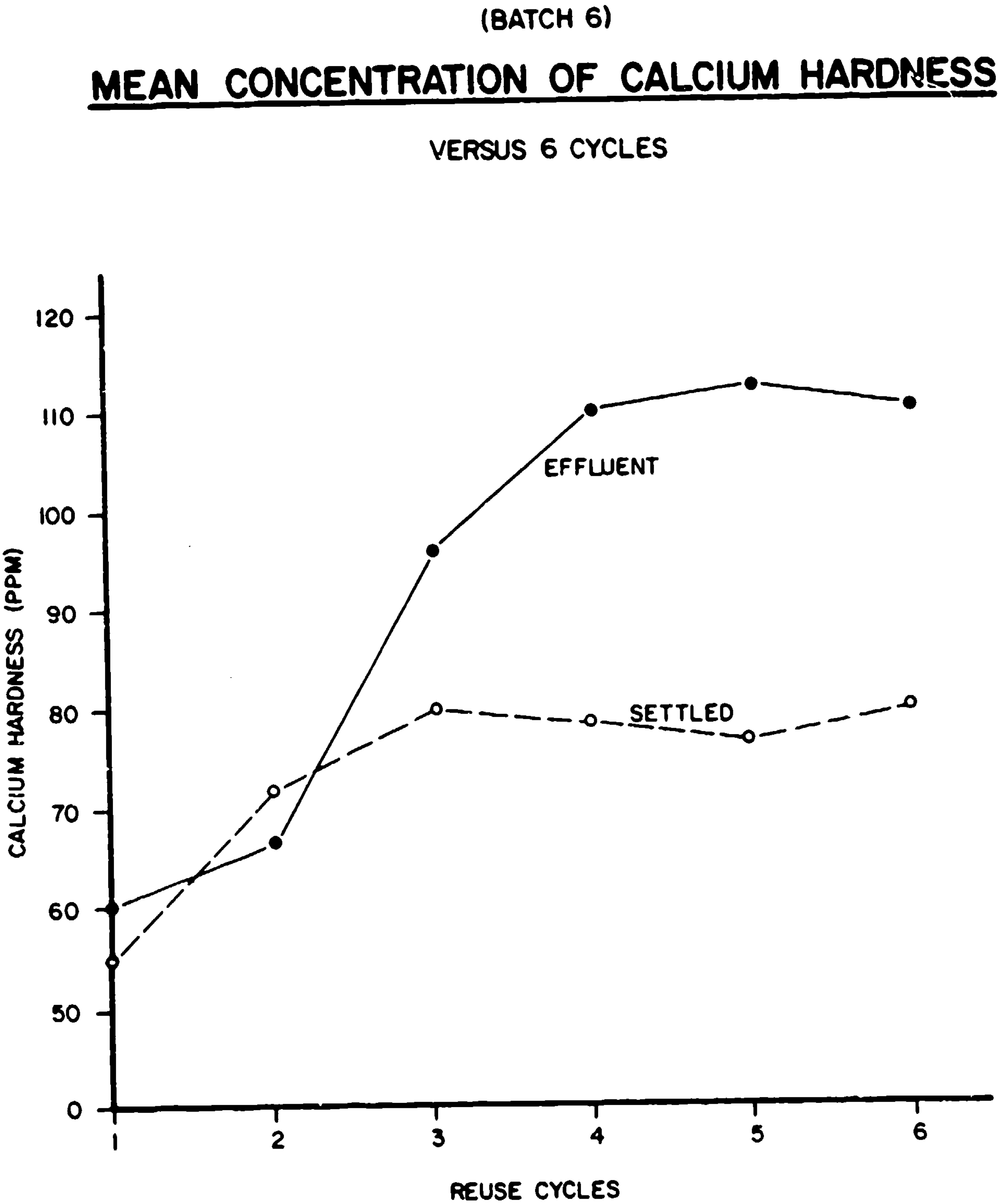


Figure 17. Comparison of mean calcium hardness concentration in washer effluent and treated settled waters during various reuse cycles of batch run 6.

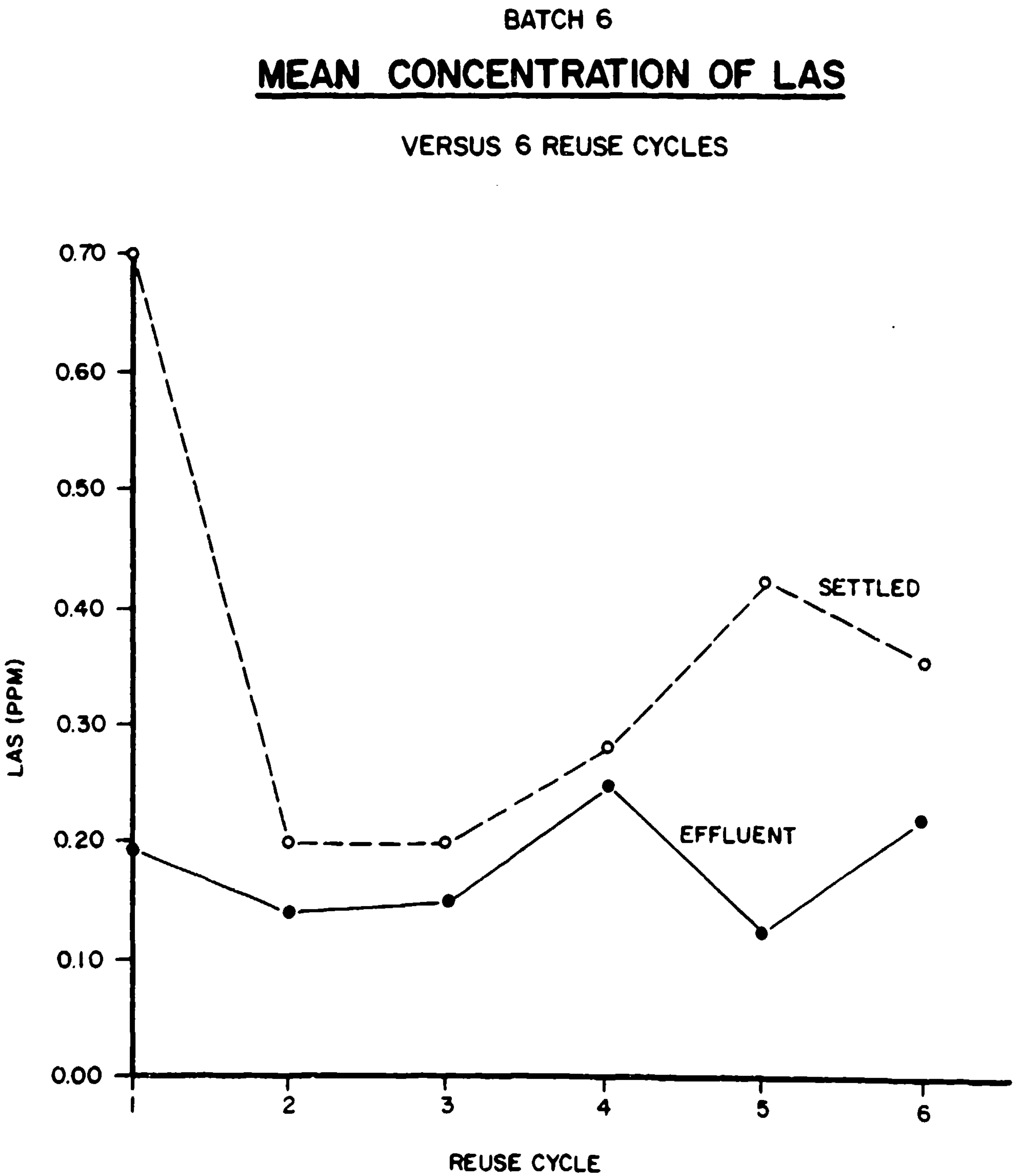


Figure 18. Comparison of mean LAS concentration in washer effluent and treated settled waters during various reuse cycles of batch run 6.

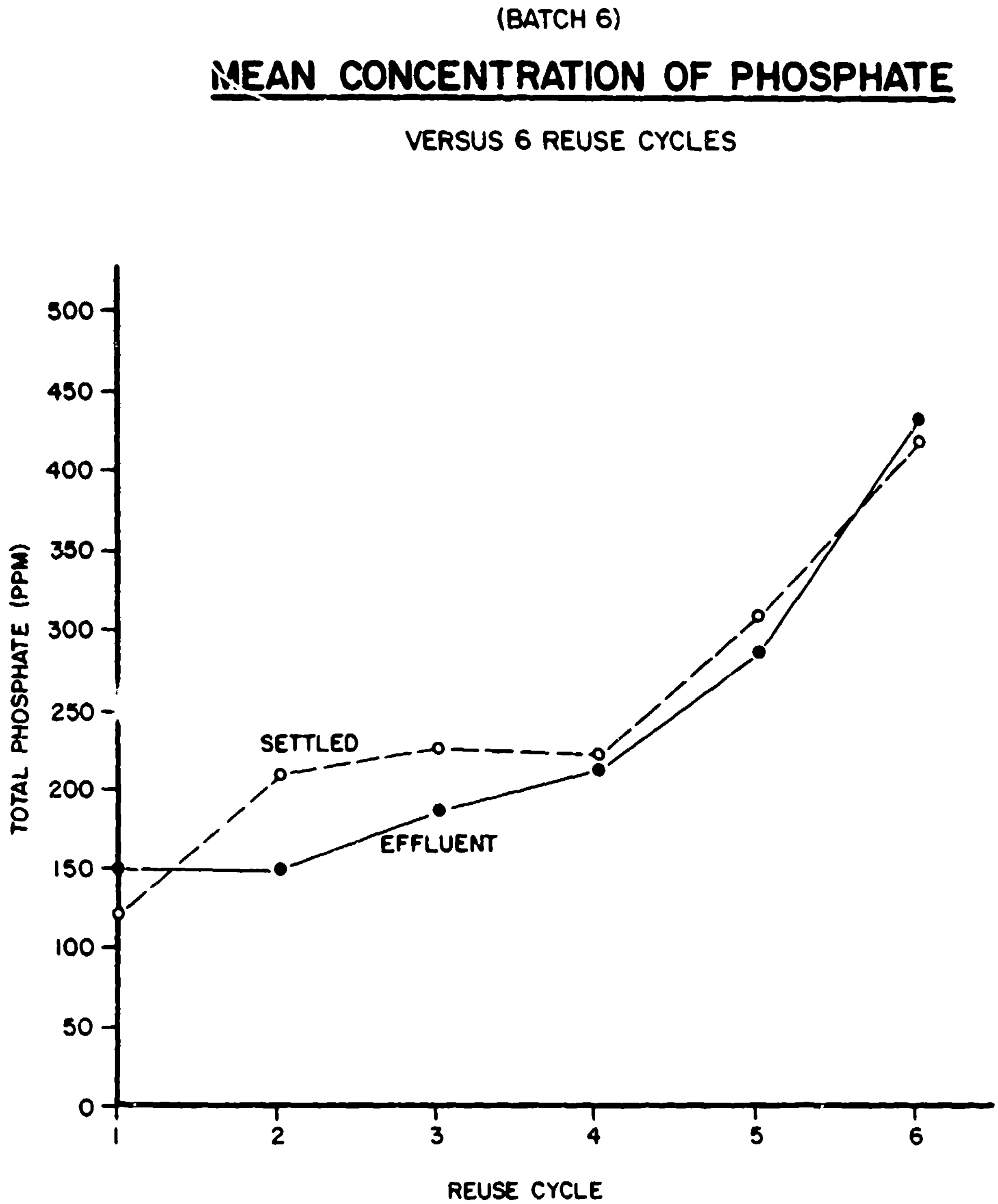


Figure 19. Comparison of mean total phosphate concentration in washer effluent and treated settled waters during various reuse cycles of batch run 6.

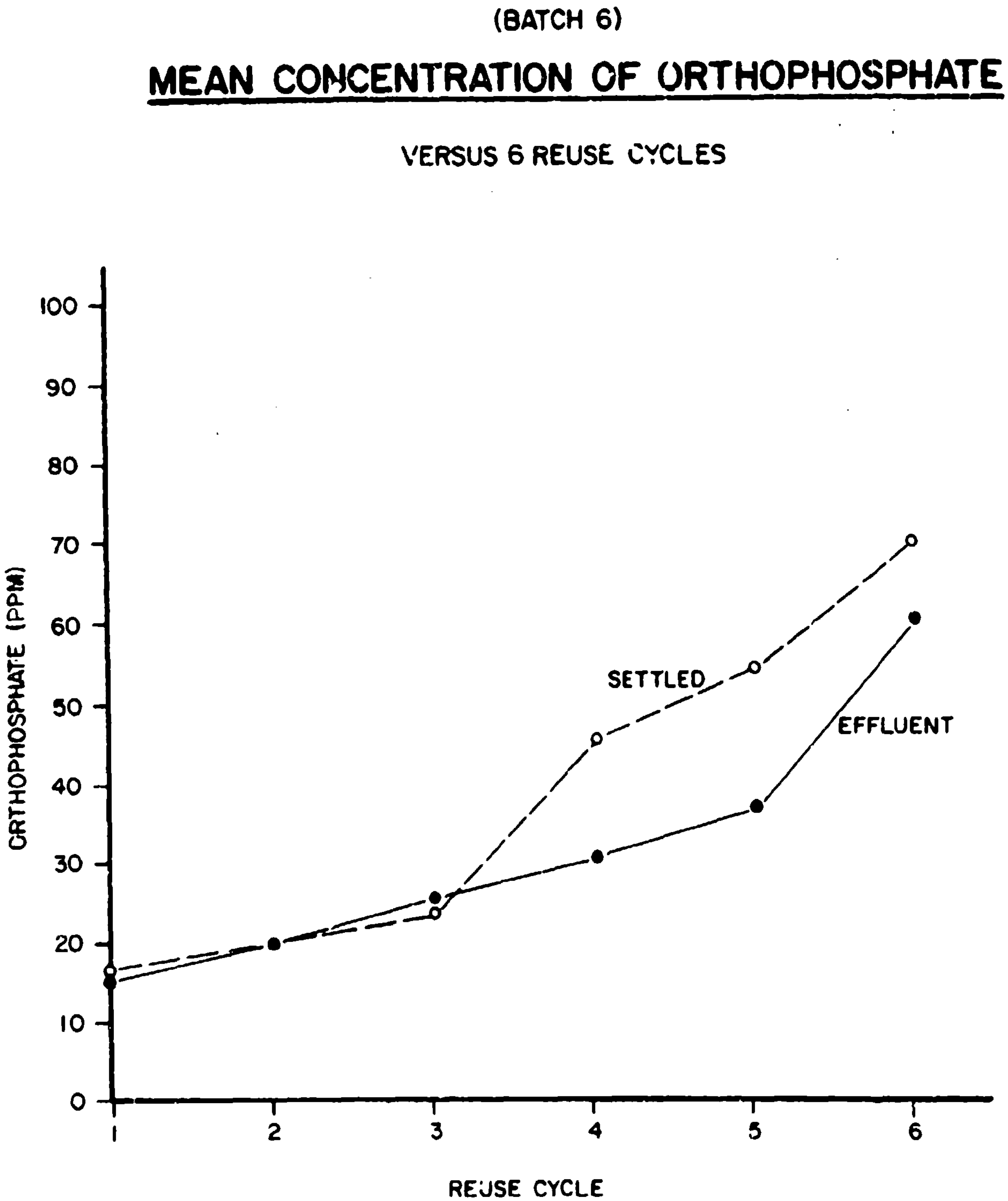


Figure 20. Comparison of mean orthophosphate concentration in washer effluent and treated settled waters during various reuse cycles of batch run 6.

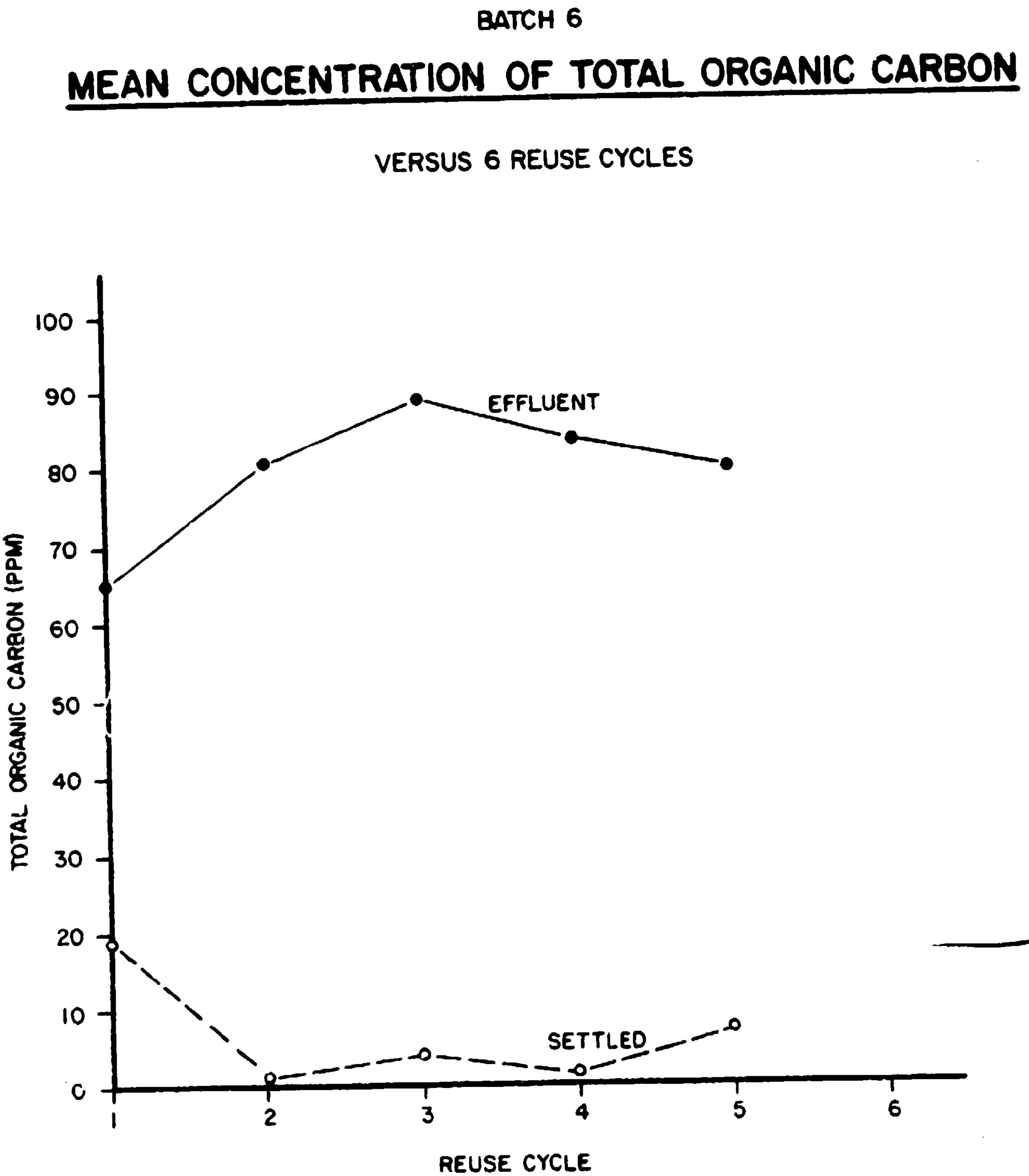


Figure 21. Comparison of mean TOC concentration in washer effluent and treated settled waters during various reuse cycles of batch run 6.

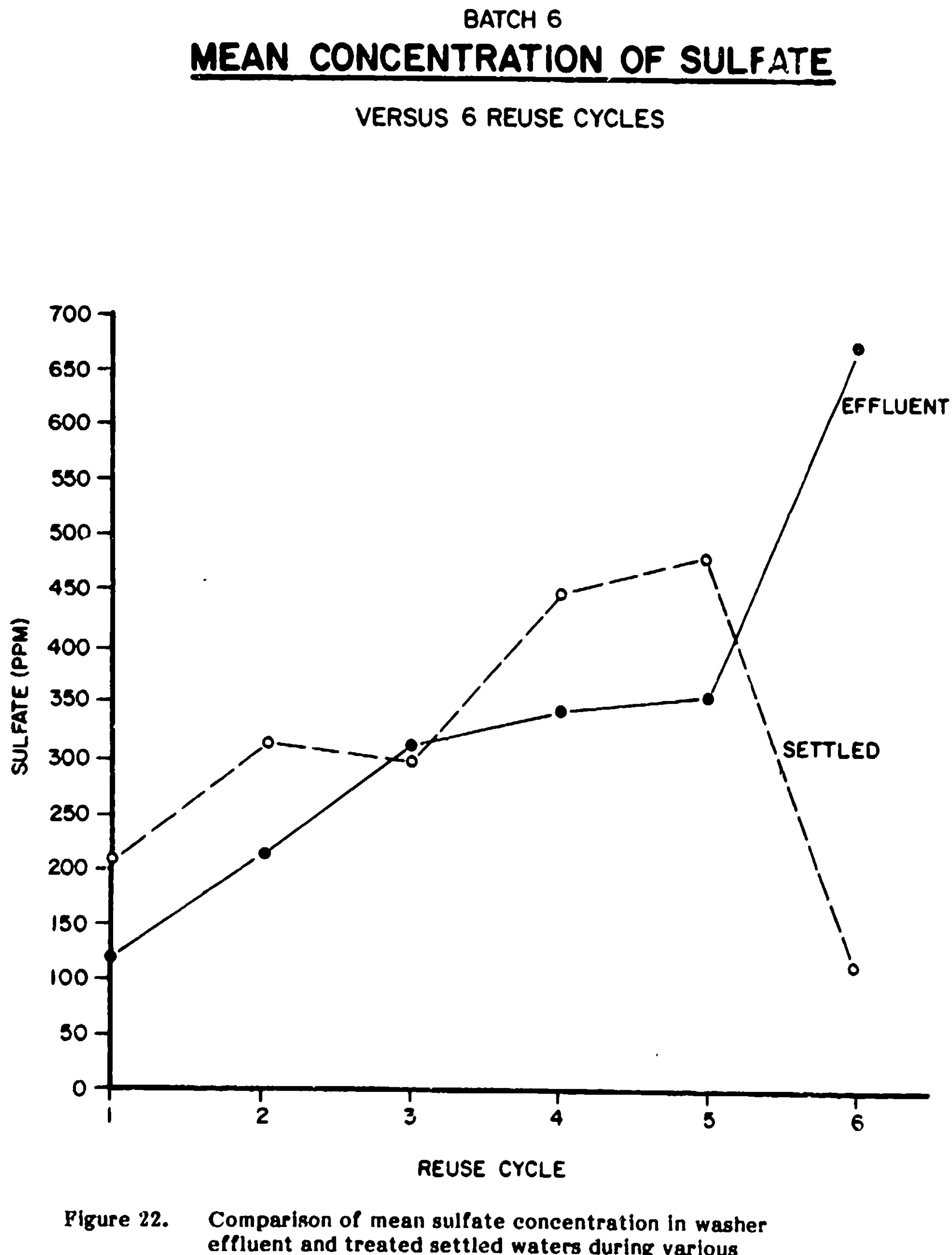


Figure 22. Comparison of mean sulfate concentration in washer effluent and treated settled waters during various reuse cycles of batch run 6.

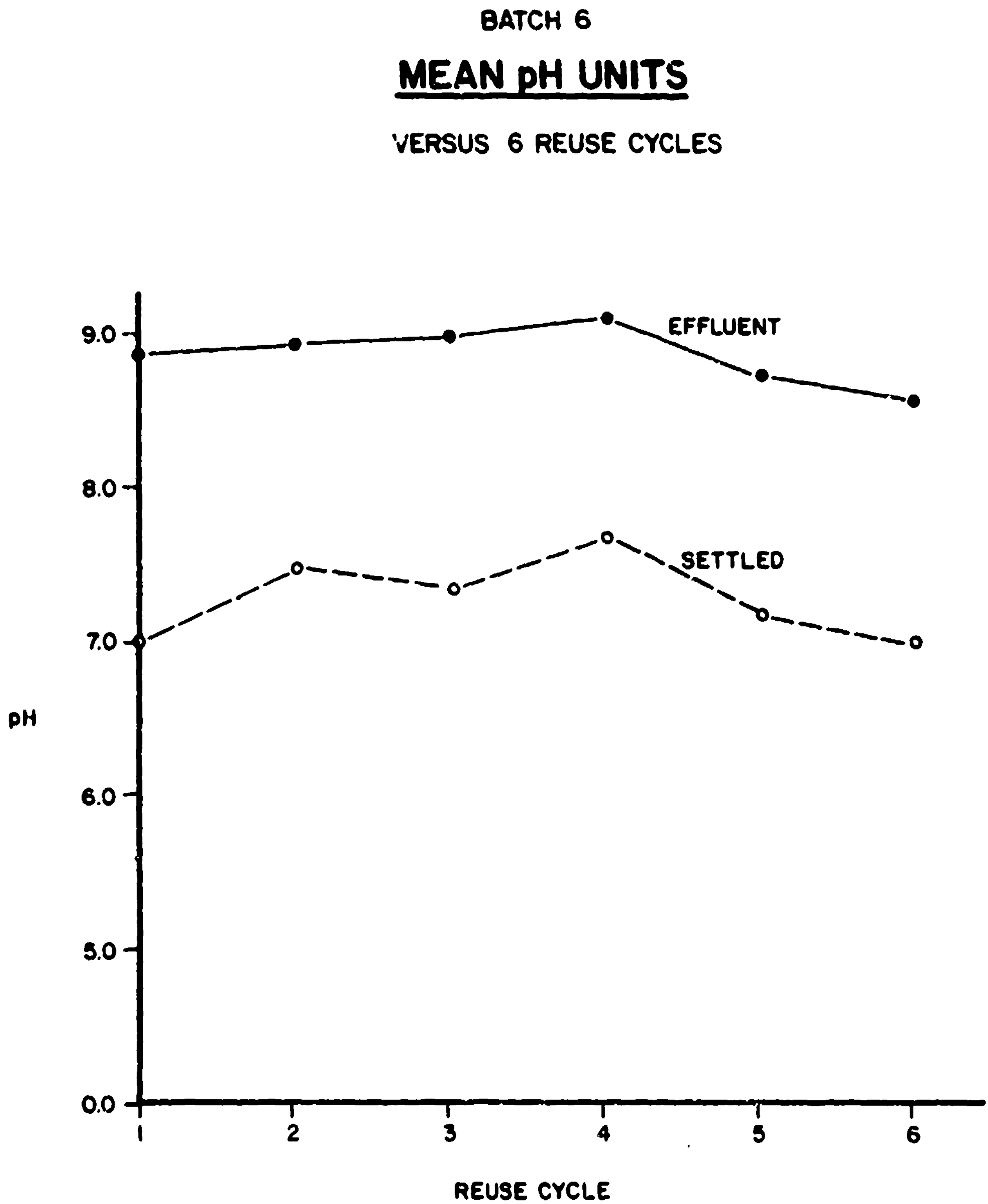


Figure 23. Comparison of mean pH in washer effluent and treated settled waters during various reuse cycles of batch run 6.

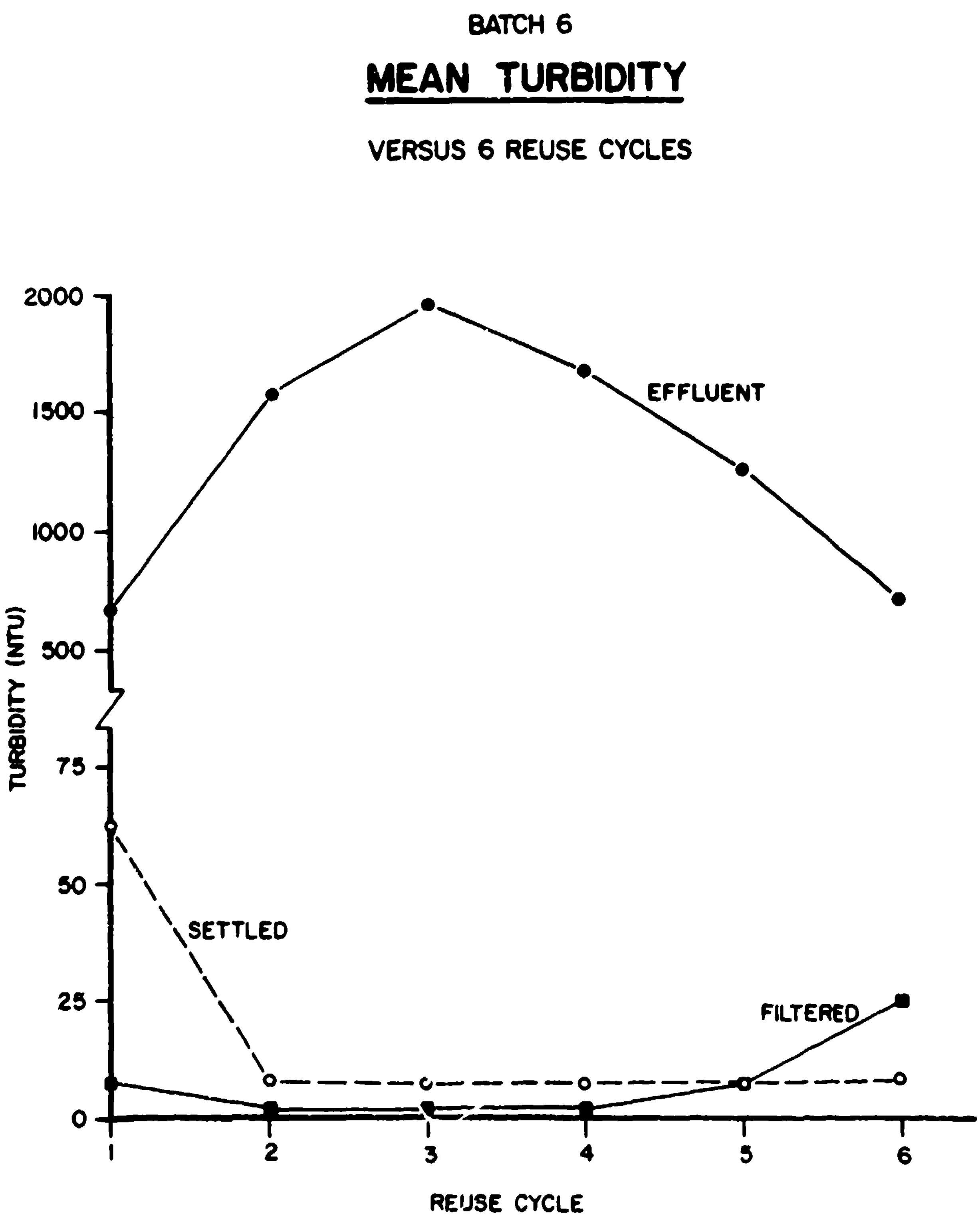


Figure 24. Comparison of mean turbidity in washer effluent and treated settled and filtered waters during various reuse cycles of batch run 6.

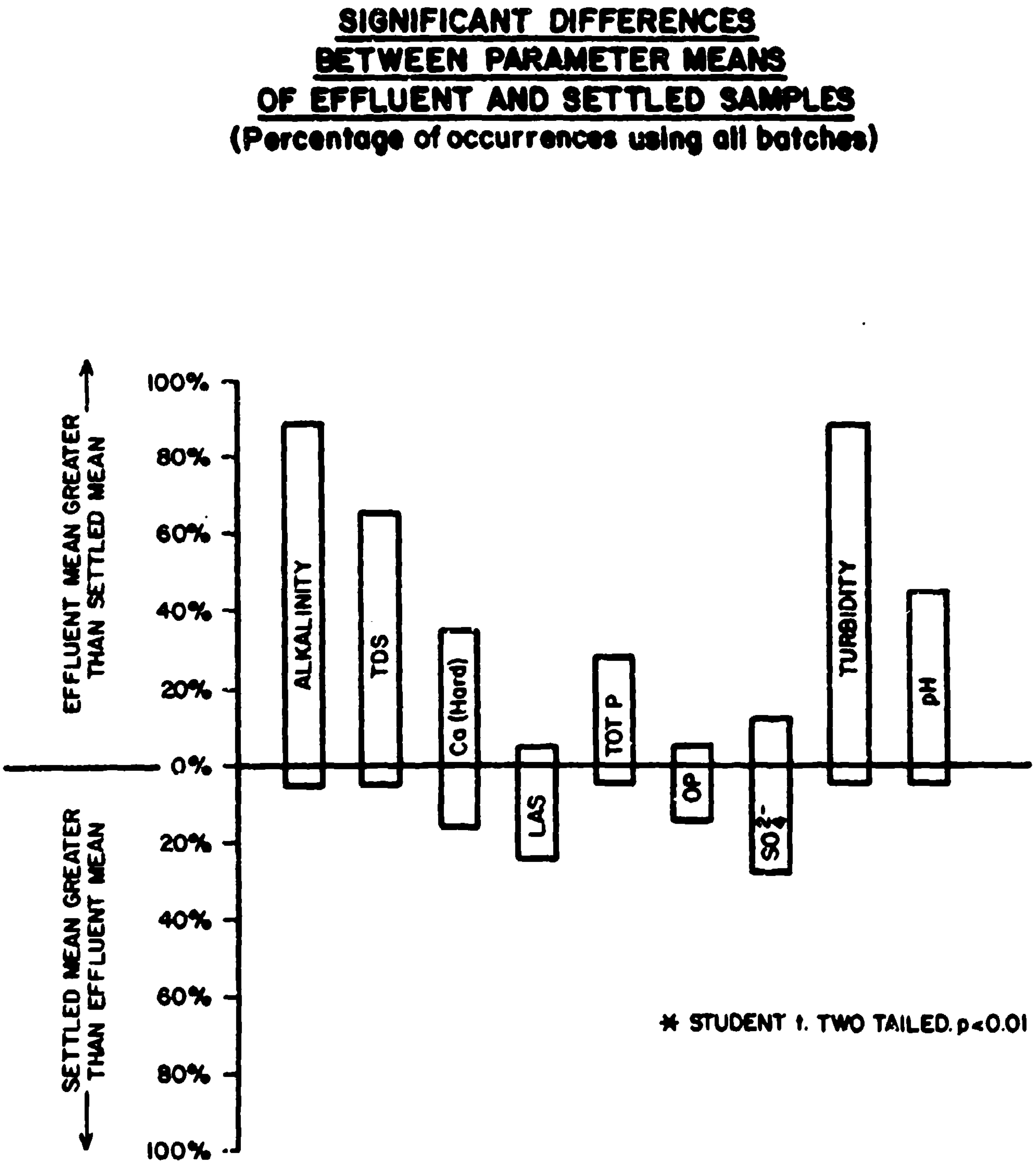


Figure 25. Comparison of occurrences of significant difference between washer effluent and treated settled waters during various parameters.

4 DATA ANALYSIS

The following discussion analyzes the data presented in Chapter 3. A separate analysis is presented for each test batch (Batches 4, 5, and 6), with interpretations provided on trends noted in key test parameters.

Batch 4

As shown in Table 1, Batch 4 was recycled only three times; the specified carbon (6.5 lb) was added only in the first wastewater treatment cycle, but none was added for cycles 2 and 3. Acid was added for pH adjustment to form the floc needed for efficient settling.

Table 3 shows that although a significant difference was observed for turbidity between effluent and settled and filtered waters, only in cycle 1 (when 6.5 lb of carbon were added) did the filtered water meet the OTSG interim quality criteria for this parameter. This shows that carbon addition for each cycle is essential; it provides the required particles for beginning floc formation.

Batch 5

Table 1 shows that Batch 5 was recycled eight times, during which pH was adjusted with 100 mL of acid; 6.5 lb of carbon were added each time a reuse cycle was treated.

All of the laundry water used is not recoverable, as noted by the amount of makeup water required for each cycle (Table 1). The washed clothing retains some water that could not be removed during extraction. In wastewater treatment, the main loss of water is due to backwashing the DE filter. Although this filter is designed to use a minimum amount of water for backwash, the frequency of backwash produces cumulative water losses and therefore increases makeup water requirements. In Batch 5, the makeup water was about 11 percent of the total required for eight cycles.

Table 4 shows that for eight cycles, filtered water turbidity met OTSG interim quality criteria seven times. Only in the first cycle did the filtered water exceed the interim criteria (11 vs. 5). Adding 100 mL of acid to each effluent for each cycle adjusted the pH to a range effective for floc formation although slightly exceeding the OTSG interim quality criteria.

Total organic carbon measured for each of the eight cycles in the effluent and settled waters showed a high degree of removal in each treatment cycle. In each case, OTSG criteria were met (without chlorination), with the ranges of TOC values recorded being 62 to 87 parts per million (ppm) for the effluent water and 0.1 to 2.3 ppm for the settled waters. Figure 11 shows the mean concentrations of TOC for both the effluent and settled waters.

The treatment procedure followed for Batch 5 was very effective in meeting OTSG quality criteria. Additional reuse cycles could have been continued; however, because of time and budget constraints and the requirement to study the effects of reduced carbon dosage, the work was stopped after eight cycles.

Batch 6

As shown in Table 1, Batch 6 was recycled six times, during which pH was adjusted with 100 mL of acid; 6.5 lb of carbon were added only for cycles 1 and 2. To examine the feasibility of reducing the amount of carbon added, it was reduced to 4.0 lb in cycle 3, 2.0 lb in cycle 4, and eliminated for cycles 5 and 6.

The quantity of makeup water used in Batch 6 was about 7 percent of the total amount of laundry water required for six washing cycles. The total amount of makeup water was less than in the previous batch because the DE filter was backwashed less frequently per cycle. In several cycles, 500 gal of wastewater were filtered with only one charge of DE; i.e., the filter had to be backwashed once per tankful. This condition represents effective coagulation and settling of the carbon slurries with a substantial savings in diatomaceous earth. The efficiency of wastewater filtering improves when carbon slurry settling improves. Resuspension of carbon sludge from previous cycles definitely improves the settling characteristic of carbon/polymer slurry. Consequently, the first cycle of each batch was always the most difficult to filter.

OTSG criteria for turbidity of the filtered water were exceeded for cycle 1, met for cycles 2, 3 and 4, and exceeded when no carbon was added in cycles 5 and 6. Table 6 shows the observed turbidity values for the settled and filtered waters and the amount of carbon added for each cycle.

The OTSG interim quality criteria do not address TOC, but rather require the reclaimed water to carry a free available chlorine residual instead. The values reported here are those without any chlorination of the water and show the effectiveness of "organics" removal by the treatment system studied. Disinfection by adding chlorine is another step in the treatment process and is very simple to do in the field.

TOC measured for each of the six cycles in the effluent and settled waters showed a high degree of "organics" removal in cycles 2, 3, and 4. For cycle 1, the removal efficiency was about 71 percent. For Batch 5, TOC removal in cycle 1 was 80.6 percent, while that shown for cycles 2 through 4 exceeded 99 percent in each case. For cycles 4 and 5, removal efficiency was 90.8 percent. No TOC measurements were recorded for cycle 6. Figure 21 shows the mean concentrations of TOC for both the effluent and settled waters.

Table 6
Turbitity of Settled and Filtered Waters
During Batch Run 6

Cycle	Quantity of Carbon Added (lb)	Turbidity (NTU) Settled Water	Filtered Water
1	6.5	65	10
2	6.5	8	1
3	4.0	6	0.8
4	2.0	9	0.75
5	0	27	7.4
6	0	99	27

Inorganic Constituents

Although the OTSG criteria do not address specific inorganic constituents (or contaminants), this study examined selected inorganic parameters. The purpose was to determine their change or buildup in concentration throughout the various reuse cycles, with the focus on settled rather than effluent waters. The rationale was to document their impact as either an operational factor or a potential health-related concern. Since there are no measurement criteria or values, the data reported here are for documentation and further review and evaluation by OTSG personnel.

Tables 7 and 8 show the measured means for selected inorganic constituents for Batches 5 and 6, indicating their respective trends. The following observations can be made from the data:

1. Total dissolved solids increased steadily for the settled water at an approximate rate of 150 to 200 ppm per cycle for both Batches 5 and 6, with a total increase of about 1585 ppm over eight cycles for Batch 5 and 1120 ppm over six cycles for Batch 6.

Table 7

Mean Concentration of Selected Inorganics by Reuse Cycle for Settled Water During Batch Run 5

	Concentration (mg/L)							
Cycle	1	2	3	4	5	6	7	8
Inorganic Constituent								
Total Dissolved Solids	767	1005	1194	1509	1695	1795	2036	2351
Total Phosphate	93	64	144	214	160	250	344	421
Ortho-Phosphate	12	16	20	37	54	53	63	75
Sulfate	180	249	403	450	619	142	670	883

Table 8

Mean Concentration of Selected Inorganics by Reuse Cycle for Settled Water During Batch Run 6

	Concentration (ppm)					
Cycle	1	2	3	4	5	6
Inorganic Constituent						
Total Dissolved Solids	934	1018	1267	1585	1700	2055
Total Phosphate	129	210	229	225	308	424
Ortho-Phosphate	18	21	25	45	56	69
Sulfate	209	318	305	453	487	112

2. Total phosphates for Batch 5 showed a steady increase of about 330 ppm over the eight cycles, with the increment increasing at each cycle, indicating a pattern of more rapid buildup. For Batch 6, a similar pattern was observed, except that the increment between cycles when no carbon was added (5 and 6) tended to be greater here than for similar cycles in Batch 5.

3. Orthophosphates tended to increase regularly from cycle to cycle for both Batches 5 and 6, with a total increase of about 50 ppm for each.

4. Sulfates showed an increasing trend over each cycle for Batch 5, giving a total increase of about 700 ppm over the eight cycles. Although the increasing tendency was somewhat variable, a rough estimate would indicate an approximate gradient of 150 to 200 ppm per cycle, given the treatment procedures followed in this batch. For Batch 6, the pattern was somewhat similar, except for cycle 6, which was an exception to the increasing trend.

Wastewater Treatment Effectiveness

Figure 26 shows typical samples of laundry wastewater as it was processed through the various stages of the renovation process. Of particular note is the wide spectrum of clarity (decrease in turbidity) obtained through the unit processes of coagulation (with pH adjustment if necessary), settling, and diatomaceous earth filtration. Turbidity levels shown range from about 700 NTU in the effluent, 20 NTU in the settled water, and 1 NTU in the filtered water. Therefore, the laundry wastewater recycling system--a coagulation/filtration batch treatment process--is a viable method of effectively treating laundry wastewater for recycle in laundry units. The system's simplicity of equipment and treatment methodology make it operable by enlisted laundry specialists after minimal training.

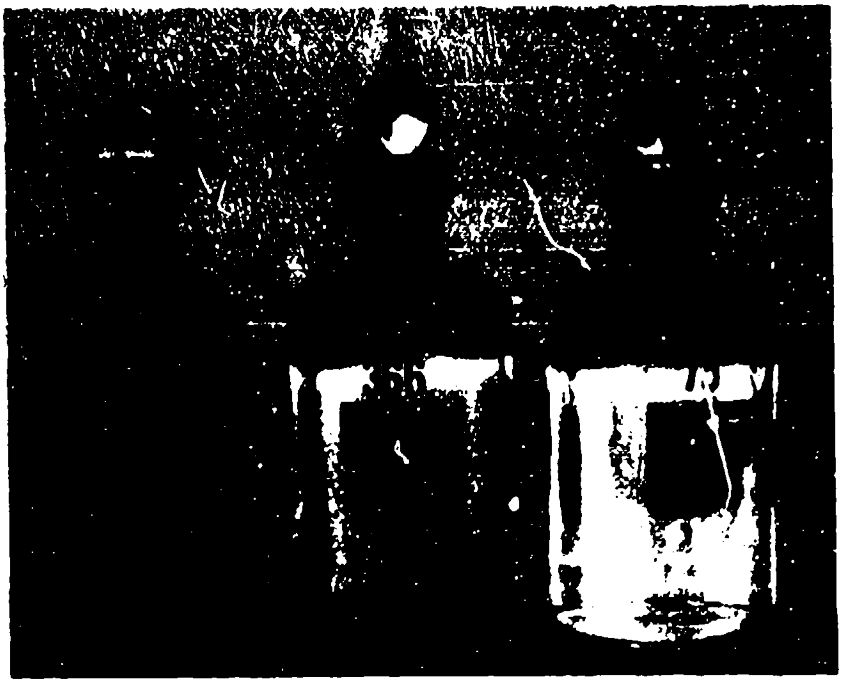


Figure 26. Laundry wastewater appearance during various stages of recycling.

5 TRAINING PROGRAM

A preliminary program of instruction (POI) was developed based on the task and skill analysis of the proposed field version of the laundry wastewater recycling system shown in Figure 27. Training conducted in accordance with the POI would be given to Army enlisted personnel attending advanced individual training for MOS 57E--laundry specialist. The POI may be adapted for use in training AFSC 611 XO personnel.

Task and Skill Analysis

Appendix A provides the Task and Skill Analysis performed in accordance with Army regulations. This analysis indicates that two members of a laundry section, which is organic to the Field Service Company (General Support), would be required to deploy and disassemble the FLWRS. However, only one enlisted person would be required to operate the system properly during a normal 10-hour shift.

A typical Army laundry section consists of a section chief and 13 laundry specialists (see Appendix B). This level of staffing permits a laundry to operate 20 hours (two 10-hour shifts) per day, 7 days per week. One laundry specialist is designated as driver of the cargo truck and trailer assigned to the laundry section. The U.S. Army Training and Doctrine Command must determine whether the driver and some other members of the Section can operate a FLWRS, or whether the section must be augmented with additional personnel.

The Task and Skill Analysis (Appendix A) often refers to a hypothetical manual on the operation and maintenance of the FLWRS. Such a document would be produced if the Army approved use of the FLWRS.

Program of Instruction

Appendix C presents the suggested POI for laundry specialists. The primary focus of the instruction is the treatment procedure and water sampling and testing. Sixty-five percent of the total 40 hours indicated in the POI would be devoted to lead-through practical exercises to ensure proficiency in measuring the proper amounts of chemicals, operation of the diatomaceous filter, and water sampling/testing procedures. A relatively small amount of time would be allotted to system installation and disassembly because students will already be familiar with much of the equipment.

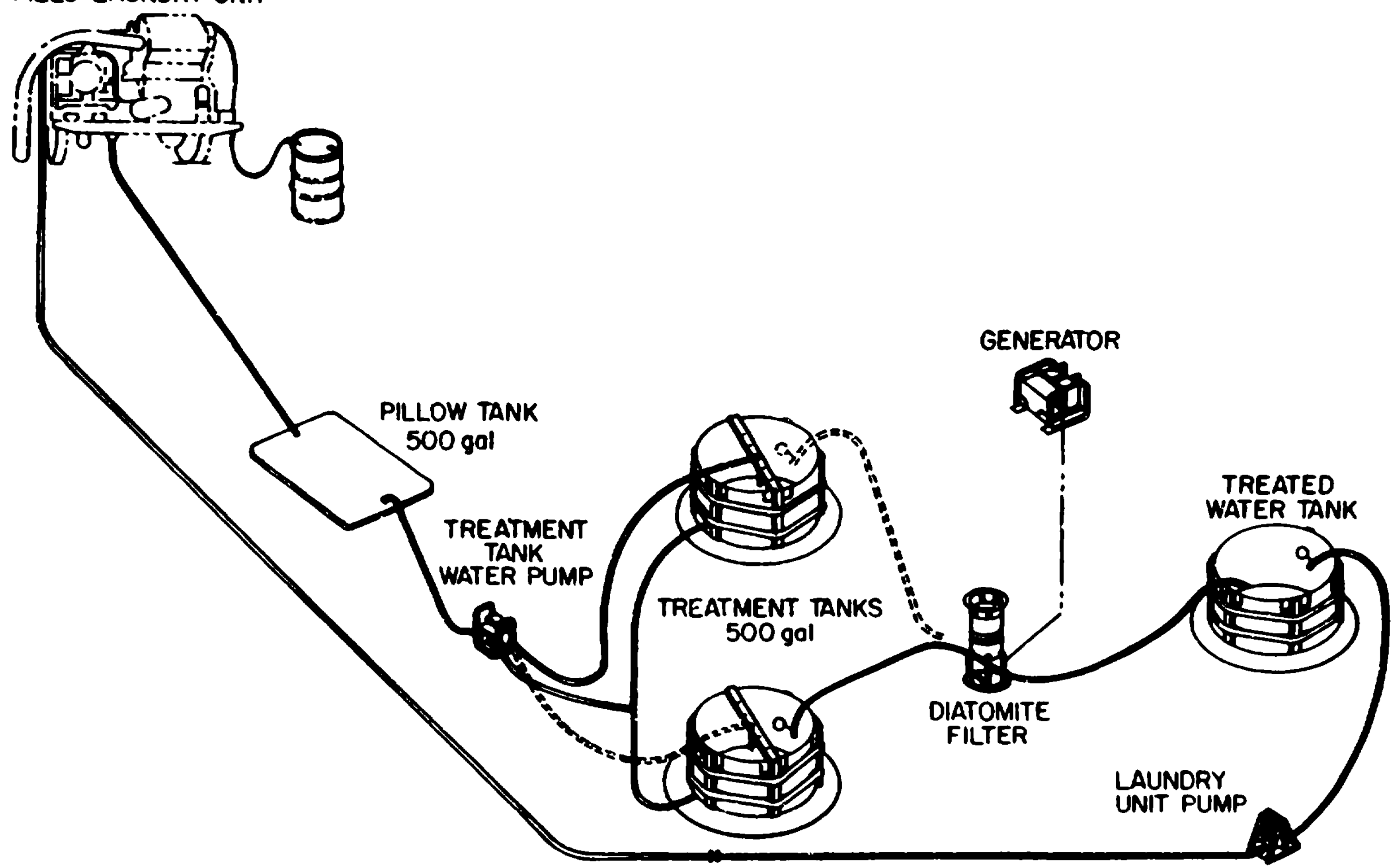


Figure 27. Schematic of field laundry wastewater recycling system.

6 WATER QUALITY MONITORING

The wastewater treatment techniques designed for the FLWRS were tested in the laboratory to validate their effectiveness. A comprehensive battery of tests was performed to evaluate water quality during treatment, although when a FLWRS is deployed in the field, the operator need not conduct similar extensive water quality testing. Analysis of the laboratory test results readily revealed which tests could be performed easily in the field, yet still provide sufficient data to determine system viability.

System viability in the field depends on whether the treatment process is providing recyclable water of appropriate quality. A field operator can determine water quality by performing just four critical sampling and testing procedures: two pH measurements, a turbidity evaluation, and a residual chlorine measurement. Although care should be taken when taking these measurements, it is neither necessary nor possible to conduct these tests with laboratory precision in the field.

To supplement water quality results, an operator must also observe the treatment process. The most critical area is periodically checking the amount of suds produced by the laundry detergent during washing. The rate of settling after the polymers have been added to the wastewater must also be observed.

Water Sampling and Testing

The following describes the sampling and testing procedures to be performed by a laundry specialist when operating the FLWRS:

pH

Two separate pH measurements should be taken on each 500 gal of laundry wastewater being treated. The first involves measuring and adjusting, if necessary, the wastewater pH to ensure that it is between 6.0 and 8.0 before starting the treatment process. The second test is performed on the filtered water to ensure that its pH is between 6.5 and 7.5 before the water is reused for washing another load of clothes.

The first test on the 500 gal of wash- and rinsewater uses litmus paper. In most cases, the colormetric reading will indicate an alkaline condition because of the dirt and the body salts from perspiration on the clothing and the detergent in the washwater discharge. Under these conditions, the operator incrementally adds acid (e.g., sulfuric acid) to the tank to reduce the pH to a neutral range (6.0 to 8.0) where optimum floc is formed once the polymers and carbon are added to the wastewater. However, if the pH is less than 6.0, sodium carbonate is added to increase it. Upon startup, several pH readings may be needed before the proper amount of acid can be determined; however, a single reading may only be needed thereafter to verify that conditions have not changed.

The second pH test on the filtered water uses a standard color comparator equipped with pH discs. This is a more accurate method of measurement than litmus paper and is more appropriate for testing clean, treated water, which must be in the range of 6.5 to 7.5 to meet OTSG criteria.

Chlorine

Treated water must be adequately disinfected before being recycled through the laundry unit. Calcium hypochlorite--a chemical already in the Army supply system--is used for this purpose.

Free residual chlorine is measured in the treated water storage tank after calcium hypochlorite is added manually to the collection tank and after the chemical is thoroughly mixed with the water during the filling process. Chlorine tests are performed using a standard color comparator equipped with chlorine discs and DPD* tablets.

Turbidity

Turbidity of the treated water should be measured to verify that it is less than 5 NTU, as set forth in OTSG Interim Water Quality Criteria. A precise measurement is not required for the FLWRS; therefore, use of a simple turbidimeter to determine the relative clarity of a water sample is recommended. Experience has shown that a soldier needs only a little experience with this device to determine whether a 1000-mL sample of water is less or greater than 5 turbidity units.

Operational Monitoring

A laundry specialist should periodically observe the amount of suds in the washer to verify that enough detergent has been added. Low sudsing can also occur when the calcium hardness level builds up after wastewater has been recycled a number of times. When this happens, the operator of the FLWRS should be prepared to stop further recycling and recharge this system with fresh water.

Settlement of suspended solids in the wastewater normally occurs quickly after the addition of activated carbon and polymers. If it does not, the operator must decide whether the washwater has been neutralized properly or whether the prescribed amounts of each type of polymer have been added.

Water Quality Test Equipment

The Army has two Water Quality Analysis Sets (WQAS, not in Air Force inventory): one used by water purification unit operators, and the other by preventive medicine teams. These sets, which consist of water test kits with necessary reagent chemicals, are packaged in rugged, watertight cases. Each set weighs about 55 lb, has a volume of about 4.5 cu ft, and costs more than $1000.

The WQAS-Engineer** provides on-site information to determine the type of purification equipment required, monitors the equipment operations, and detects water contamination caused by chemical agents.

The main components of the WQAS are:

- Alkalinity test kit

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*N, N-diethyl-p-phenylene diamine.
**Used by operators of water purification units.

- Turbidity test kit
- Sulfate test kit
- pH chlorine/residual test kit
- Hardness test kit
- Color test kit
- Low-range chloride test kit
- Conductivity meter
- Water testing kit for chemical agents AN-M2
- Refill kit, chemical detector, V-G, ABC-M30
- Supporting labware and reagents

The WQAS-Preventive Medicine is designed for on-site monitoring of the quality of raw water sources, wastewater effluents, and drinking water produced.

The main components of the set are:

- Acidity test kit
- High-range chloride test kit
- Iron test kit
- Dissolved oxygen test kit
- Zinc test kit
- Multi-purpose spectrophotometer
  - --Fluoride
  - --Nitrogen, ammonia
  - --Ferrous iron
  - --Ferric iron

The Belvoir Research and Development Center is developing water quality analysis sets to replace the two described above. However, both the old and new sets contain more test kits and equipment than needed to monitor laundry wastewater recycling operations. In lieu of standard-issue WQAS, it is recommended that just the test equipment listed below be provided to the Laundry Section of a Field Service Company:

- Litmus (pH) paper, range 6.0 - 8.0

- Color comparator with pH and chlorine discs
- Turbidity tube

A special Water Quality Analysis Set made up of the above components should be relatively inexpensive (less than $100). More importantly, the simplicity of each item will enable a laundry specialist to learn quickly how to use them and develop confidence in his/her ability to control the recycling process.

7 HEALTH IMPLICATIONS OF RECYCLING LAUNDRY WASTEWATER

There is very little published information describing either the expected occurrence of specific chemicals in laundry wastewater or their related health effects. Generally, most of the available data[3] focus on criteria for generating potable water after recycling. Therefore, the related health effects information focuses on frequent oral or direct dermal contact with recycled water. In the case of the FLWRS, such stringent direct-contact criteria may not apply. The recycled and FLWRS-treated laundry wastewater will be used only for laundry. Direct general troop contact with the treated water (i.e., consumption or bathing) is neither intended nor likely to occur, except for individual(s) operating the laundry facilities, who may have an increased risk of chemical exposure. The following sections provide more specific discussions of the route(s) of exposure and contaminants of concern.

Exposure

The primary health concern for a field unit using the FLWRS would be skin contact with chemical deposits present on clothing or linens after laundering. Therefore, dermal contact or absorption is the primary route of exposure. No information was available in the literature about health hazards associated with anhydrous dermal contact with chemicals likely to occur as deposits after laundering; however, compounds that are skin irritants or cause skin sensitization are likely to be of greatest concern. One method for evaluating potential health effects would be skin patch tests using laundry wastewater concentrates dried onto fabric.

Contact with moisture could enhance skin irritability or absorption of chemical deposits. In the field, such contact could occur through perspiration, rain, immersion in a lake or stream, or contact with wet ground. The moisture's pH may also greatly affect the actual absorption or solubility of a given compound.

The hazard associated with any compound must be evaluated individually, based on its physical, chemical, and toxicological properties. Chemical interactions may also occur in laundry water that may result in additional compounds of higher risk being deposited. The synergistic effects of several compounds present at the same time may also affect an overall risk assessment.

Special Population at Risk

Operators of FLWRS facilities may have a different risk of chemical exposure than the general field unit population. They would potentially have direct contact with the laundry water at all stages of treatment. However, use of protective gloves and boots would minimize any potential hazard associated with such direct contact. Use of protective equipment would also prevent direct contact with the sulfuric acid used for pH adjustment during water treatment. In its concentrated form, this strong acid can cause severe skin burns. Other water treatment chemicals do not have similar handling hazards.

[3] *Characterization Studies of Wastewater Generated from Military Installations*, CALSPAN Report No. ND-5296-M-1 (CALSPAN, April 1973); *Evaluation of Health Effects Data on Reuse of Shower and Laundry Waters by Field Army Units* (Walden Division of ABCOR, April 1979).

Depending on the chemicals present in the laundry water during all phases of use or treatment, any volatile organic chemicals would be of particular concern. Compounds with a high vapor pressure or a high Henry's Law Constant would tend to leave the water phase and enter the air. This vaporization is accentuated when the water is turbulent or agitated, such as when laundry wash- or rinsewater is transferred to the large holding or treatment tank before coagulation or when mixing is done during coagulation. The risk of respiratory exposure depends entirely upon the nature of the chemicals present in the laundry water and is directly related to the chemicals that appear in the soiled clothing or linens. It is unlikely that high vapor concentrations will occur. Operating the FLWRS in a well-ventilated or unenclosed area would tend to dissipate all but the densest vapors and preclude the need for protective breathing devices. Again, the relative risk can only be determined with respect to specific compounds.

Chemical Content of Laundry Wastewater

The chemicals in recycled laundry wastewater consist mostly of those found in synthetic detergents, bleaches, and soaps. There is also potential added chemical input from water treatment chemicals and various constituents present in soiled clothing or linens. Previous studies have reported typical wastewater characteristics for various military installations.[4] The data in Table 9 summarize some chemical characteristics measured for field laundry wastewaters compared to data for commercial laundry wastewater. It appears that the major difference between military and commercial laundry wastewater is that both the pH and total alkalinity are lower for military effluents.

When the FLWRS is used in the field, hospital laundry may be combined with general laundry. This could add a few specific contaminants, such as blood, disinfectants, drugs, laboratory chemicals, and X-ray processing chemicals.[5] Specific contaminants associated with these sources include mercury, barium, beryllium, boron, chromium, and lead. There are no data available indicating skin sensitivity to these contaminants; however, ingestion of most heavy metals produces adverse health effects.

Water Treatment Chemicals

The following chemicals, all of which are readily available commercially, are added to laundry wastewater during water treatment:

- Polymer Type I, a cationic coagulant
- Polymer Type II, an anionic coagulant
- Sulfuric acid for pH adjustment
- Soda ash (anhydrous sodium carbonate) for pH adjustment

[4] *Characterization Studies of Wastewater*; J.T. Bandy, M. Messenger, and E. Smith, *A Procedure for Evaluating Subpotable Water Reuse Potential at Army Fixed Facilities*, Technical Report N-109/ADA111191 (U.S. Army Construction Engineering Research Laboratory [USA-CERL], 1981).

[5] *Characterization of Studies of Wastewater*; J. T. Bandy, M. Messenger, and E. Smith.

Table 9

Characteristics of Laundry Wastewater
(Adapted from Characterization Studies of Wastewater Generated from Military Installations, CALSPAN Report No. ND-5296-M-1 [CALSPAN, April 1973]).

Parameter (mg/L except as noted)	**Military Field Unit Ave.**	**Max.**	**Commercial Range**
Turbidity, JTU*	1,362.7	3,800.0	
pH, Unit	7.4	7.6	9.0 to 10.3
Total Dissolved Solids	500.0	800.0	
Suspended Solids	-	-	210 to 540
Total Solids	-	-	800 to 2,100
Volatile Solids	-	-	<1,500
Detergent	2.8	6.5	
Total Phosphate	75.7	128.0	
Orthophosphate	-	122.0	
Polyphosphate	-	6.0	
Sulphate	81.0	175.0	
Silicate	94.0	150.0	
Total Hardness ($CaCO_3$)	30.0	34.0	
Calcium Hardness ($CaCO_3$)	22.7	32.0	
Magnesium Hardness ($CaCO_3$)	7.3	12.0	
Total Alkalinity ($CaCO_3$)	227.0	286.0	<511
Chloride	130.0	-	
BOD, 5-day	339.0	-	370 to 635
TOC	100.2	258.0	
Oil and Grease	-	-	170 to 550

*Jackson Turbidity Unit.

- Powdered activated carbon to adsorb organic components
- Calcium hypochlorite to add chlorine for disinfection.

No adverse health effects are anticipated to result from exposure to these items. Both coagulant polymers are approved by the U.S. Environmental Protection Agency for use in drinking water systems. Their formulation and recommended doses do not produce residuals or contaminants of concern to health safety. The use of sulfuric acid to adjust pH will add sulfate to the wastewater. However, laboratory testing of the FLWRS indicated that the amount of sulfate does not approach unhealthful levels, so field operators will not have to monitor this parameter. Similarly, any additions of soda ash to adjust pH will increase the laundry wastewater's carbonate content, but this need not be measured in the field, since increasing hardness and low sudsing will reflect increases in carbonates. Also, there is no information indicating that dermal exposure to sulfate or carbonate deposits is hazardous.

Powdered activated carbon, along with anything adsorbed to those particles, is removed from the FLWRS-processed water by settlement and by the DE filtration. The field operating procedures indicate that monitoring turbidity will provide an opportunity to detect any breakdown of the settling and filtering process. If there is inadequate clarification, the potential result would be increased skin irritation due to the carbon particles trapped in laundered fabrics, or due to possible contact with organic compounds adsorbed to the carbon particles. Additions of calcium hypochlorite are evaluated based on field monitoring of chlorine levels. These data ensure that chlorine is maintained within the range that provides antimicrobial activity, but does not present a health hazard.

Contaminants Resulting From Field Activities

The most important factor influencing contamination and potential health hazards in recycled laundry water is the type of compounds occurring in soiled clothing and linens. Those kinds of compounds relate directly to field activities. As soldiers carry out their duties, their clothing comes in contact with various compounds, which then appear in the laundry wastewater.

The following are examples of groups of chemicals that may contaminate recycled military laundry water:[6]

- Munitions
- Pesticides
- Oils and greases
- Solvents.

The extent to which any of these items affect the overall health safety of recycling laundry water depends on two main factors: the toxicological properties of the individual compound, and the extent to which the compound appears in laundry wastewater. For example, few individuals may contact large amounts of a given compound during their daily routines. However, this compound may be diluted out of a range of concern due to the small proportion it contributes to overall laundry water content. In contrast, most of the troops may contact a small or moderate amount of a given compound. Because of the relative proportion, this compound may appear in the laundry wastewater at a level of concern. Such factors should be considered when decisions to recycle laundry wastewater are being made. The supporting Field Surgeon should be able to evaluate the relative hazard associated with various activities. It is possible that before being added to the general laundry, some clothing may require a preliminary rinse that will not be recycled.

It would require a significant effort to compile a comprehensive list of all potential chemicals of concern when operating a FLWRS. The compounds listed in Table 10 are examples of chemicals shown to cause dermal sensitization.[7] Some of these compounds

[6]Personal Communication, Dr. Steven Schaub; U.S. Medical Bioengineering Research and Development Laboratory, Fort Detrick, Maryland, November 13, 1984.
[7]*Evaulation of Health Effects*.

Table 10

Chemical Compounds Causing Dermal Sensitization

Compound*	Use**
Nickel	Alloys such as stainless steel, alkaline storage batteries, magnets
Protease	Meat tenderizers, some detergents
Parabens	Antimicrobials in food and drugs
Lanolin	Ointments, soaps, sun lotions
Propylene glycol	Antifreeze, solvents, hydraulic fluids, sun lotions, brake and deicing fluids, bactericide
Triethanolamine	Dry cleaning, soaps, detergents, water repellent, softening agent
Sorbic acid	Fungicide, food preservative
Hexachlorophene	Germicidal soap, veterinary medicine

*Adapted from *Evaluation of Health Effects Data on Reuse pf Shower and Laundry Waters by Field Army Units* (Walden Division of ABCOR, April 1979).
**Adapted from *The Condensed Chemical Dictionary*, 10th ed. (G. G. Hawley, Van Nostrand Reinhold Co., 1981)

also exhibit photosensitization; that is, following exposure to the compound, the skin becomes more sensitive or irritated when exposed to bright sunlight.

It is anticipated that organic compounds would be adsorbed by the activated carbon and then removed by settling and DE filtration. Of the compounds listed in Table 10, nickel could pose a problem by leaching into laundry water from stainless steel piping, holding tanks, or other laundry equipment. However, the occurrence of nickel in military field laundry water should be minimal because stainless steel components in laundry equipment are limited to the washer drum and are required to have an enamel coating.

Some concern has been expressed over potential health hazards caused by chlorination of various chemicals likely to occur in laundry wastewater. Estimates have been developed to predict the concentration of chlorinated byproducts resulting from ethanol, isopropyl alcohol, urea, lactic acid, triethanolamine, and propylene glycol.[8] Of these, only the ethanol chlorination product--2-chloroethanol (or ethylene chlorohydrin)--appears to be a possible health hazard. The estimate requires >100 ppm ethanol and

[8] *Evaluation of Health Effects.*

predicts a maximum of 25 ppm for the resulting 2-chloroethanol. However, the formation of this hazardous compound is limited by chlorine (Cl_2) concentration. The 2-chloroethanol is presented as a health hazard for several reasons:[9]

- High inhalation toxicity--2 ppm for 1 hour was fatal to rats
- Rapid skin absorption of the compound in its pure form or from water solutions
- Carcinogen analog to epichlorohydrin and/or vinyl chloride.

Even trace amounts of 2-chloroethanol, which is highly water-soluble and penetrates ordinary rubber gloves and protective clothing,[10] may present a serious health hazard. It is reasonable to expect that any 2-chloroethanol generated in laundry wastewater will be removed by adsorption onto activated carbon; however, data to verify this were not located.

Liquid ethanol would be unlikely to contact laundry water. This solvent is very volatile, and virtually all of the ethanol would vaporize before contacted clothing or linens were laundered. Also, very little chlorine would be available to react with any ethanol remaining in treated laundry wastewater. Nevertheless, due to the health dangers from 2-chloroethanol, medical authorities should be aware of potential problems if liquid ethanol enters laundry water.[11]

[9] *Evaluation of Health Effects.*
[10] *The Condensed Chemical Dictionary*, 10th ed. (G. G. Hawley, Van Nostrand Reinhold Co., 1981).
[11] J. T. Bandy, M. Messenger, and E. Smith.

8 COST ANALYSIS

A complete cost analysis of the FLWRS has not been produced at this time but will be available in a future technical report. An approximate indication of the value of the water produced is drawn from Morgan et al., who worked with mathematical modeling for evaluation of field water supply alternatives in arid and semiarid regions. They found the cost of water produced by a 600 gal per hour (gph) ROWPU (Reserve Osmosis Water Purification Unit*) to be $20.36 per 1000 gallons. This cost included fuel, polymer, chlorine, acid, sodium hexametaphosphate, and filters. Following the same reasoning, the cost for treating 6000 gal of water with the FLWRS could be estimated at $8.63 per 1000 gallons, including the cost of soda ash, polymers, carbon, calcium hypochlorite, diatomaceous earth, and fuel. Neither analysis includes capital costs, labor, or transportation and distribution. These figures indicate that the FLWRS is substantially more economical, producing 1000 gal of water for $11.73 less than the ROWPU.

The laundry section discussed in the introduction requiring 10,000 gallons of water per day can be used as an example of the possible water savings. Field laundry recycling is effective for at least three cycles. Recycling can be continued past that stage, but hardness increases and more detergent is necessary. There is also an approximate 10 percent loss of water due to water left in clothing and from filter backwash. Therefore, about a 70 percent savings in water use is indicated, which translates into 7000 gal of water per day per laundry section. This is 7000 gal of water per day which would not have to be supplied by the ROWPU and transported to the laundry, resulting in substantial savings in production cost and equipment utilization.

This savings in water when spread throughout a theater of operations can have several benefits. Most importantly, more water would be available to accommodate additional water users, either troops or equipment. Second, water transportation equipment would not be overtaxed, but could be freed for additional duty. Third, fuel consumption would be reduced from 5 gal per 1000 gal of water produced to 0.5 gal, lessening the logistics problem and resulting in substantial savings of a vital commodity.

*ROWPUs are the standard water purification device in the Army's Table of Organization and Equipment.

9 CONCLUSIONS

The laundry wastewater recycling system--a coagulation/filtration batch treatment process--is a viable method of effectively treating laundry wastewater for recycle in laundry units. The system's simplicity of equipment and treatment methodology make it operable by enlisted laundry specialists after minimal training. The guidance provided in this report will be useful for Army and Air Force personnel who must effectively operate and maintain field laundry units using recycled laundry wastewater. The following specific conclusions were reached from the operational evaluation.

- The number of treatment cycles that may be performed on a batch of laundry wastewater is affected primarily by the hardness of source water. Consequently, recycling should be terminated when insufficient suds are produced after the proper amount of detergent has been added for washing.

- The filterability of the settled wastewater in a cycle is the best indicator for making changes, during subsequent cycles, to operating procedures such as carbon dosage, duration of mixing, adjustment of pH, and settling time.

- The initial activated carbon dosage applied in the first two treatment cycles may be reduced by about 50 percent when enough sludge is available for resuspension in subsequent cycles to improve the carbon's settling characteristics.

- A training course of about 40 hours has been developed that would allow a laundry specialist to become a proficient operator of a FLWRS.

- Relatively unsophisticated water sampling and water quality testing equipment and procedures are required for a laundry specialist to control the wastewater treatment process and produce adequate quality for recycling. Field testing can be limited to measurements of pH, free chlorine, and turbidity.

- An assessment showed that no health hazard is anticipated to result from the use of detergents, bleaches, soaps, and water treatment chemicals during the operation of FLWRS. However, certain safety procedures must be observed to avoid personal injury when handling sulfuric acid and to avoid extended dermal contact with or ingestion of laundry wastewater.

- Depending on the types of activities performed by troops in the field, the primary source of potentially hazardous substances in recycled laundry waters is anticipated to be soiled clothing and linens.

METRIC CONVERSION FACTORS

1 gal	= 3.785 L
1 lb	= .4535 kg
1 ft	= .3048 m
1 oz	= 28.3495 g
1 in.	= 25.4 mm
1 cu ft	= .0283 m^3
1 psi	= 6.895 kPa
^oC	= (^oF-32) (5/9)

CITED REFERENCES

Army Regulation 611-101, *Commissioned Officer Specialty Classification System* (Department of the Army [DA], 30 October 1984).

Army Regulation 611-201, *Enlisted Career Management Fields and Military Occupational Specialties* (DA, 10 June 1984).

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Morgan, J. M., et. al., *Mathematical Modeling for Evaluation of Field Water Supply Alternatives (Arid and Semi-Arid Regions)* (VMI Research Laboratory, January 1981).

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Operator and Organizational Maintenance Manual, Laundry Wastewater Treatment Kit (NSN 4610-01-023-4536) (Systems Division of MET-PRO Corporation, Harleysville, PA, October 1977).

Sculley, J. R., et al., *Feasibility of Incorporating the Closed-Loop Concept into the Army Facilities Component System* (V. J. Ciccone and Associates, Inc., May 1983).

ACRONYMS

CT	-	collection tank
DE	-	diatomaceous earth
DPD	-	N, N-diethyl-p-propylene diamine
EI	-	examination
FLWRS	-	Field Laundry Wastewater Recycling System
FWT	-	fresh water tank
GED	-	gasoline engine-driven
GFE	-	Government-Furnished Equipment
GPH	-	gallons per hour
HT	-	holding tank
LIN	-	line item number
LAS	-	linear alkyl sulfates
LTPE	-	lead through practical exercise
MOS	-	military occupational specialty
NPSH	-	National Pipe Standard Hose
NPT	-	National Pipe Threads
NTU	-	Nessler Turbidity Units
OTSG	-	Office of the Surgeon General
POI	-	program of instruction
TOC	-	total organic carbon
TDS	-	total dissolved solids
TST	-	treatment and settling tank
WQAS	-	Water Quality Analysis Sets

APPENDIX A:

TASK AND SKILL ANALYSIS

SECTION I. SYSTEM/EQUIPMENT

A. Operation and Maintenance Concept

1. Operation - The Field Laundry Wastewater Recycling System (FLWRS) (Figure 27) will be operated by laundry teams in semi-arid regions or other areas where natural water sources are scarce. By collecting, treating, and recycling the wastewater from the field laundry units, the FLWRS will greatly reduce the amount of fresh water that must be trucked to laundry operating locations.

2. Maintenance - All FLWRS components are already in the Army inventory in various water treatment and distribution systems. Thus, no new or different maintenance procedures or concepts will be required to support the fielding of FLWRS.

B. General System/Equipment Description

The FLWRS consists of a wastewater collection tank, wastewater transfer pump, wastewater treatment tanks (two each), diatomite filter unit, laundry water storage tank, generator set, and miscellaneous hoses, valves, and fittings. The function of each major component is discussed below.

1. Wastewater Collection Tank - Receives and stores wastewater discharged by the field laundry units.

2. Wastewater Transfer Pump - Transfers wastewater from the collection tank to the wastewater treatment tank and recirculates the wastewater through the treatment tank during coagulation.

3. Wastewater Treatment Tank - Serves as a recirculation and storage vessel during coagulation and sedimentation.

4. Diatomite Filter Unit - Filters the treated wastewater and transfers it from the treatment tank to the laundry water holding tank.

5. Generator Set - Provides electric power to the filter unit.

6. Laundry Water Storage Tank - Receives and stores fresh water obtained from a field water point and treated wastewater for use by field laundry units.

C. Government-Furnished Equipment (GFE)

1. Tank, bladder, 500-gal water Line Item Number (LIN), 1 each

2. Pump, centrifugal, gasoline-engine-driven, 125 gal/min LIN P92030, 1 each

3. Tank, fabric, collapsible, 500-gal water, LIN V14744, 2 each

4. Filter assembly, diatomite, 420 gal/hr LIN, 1 each

5. Tank, fabric, collapsible, 1500-gal water, LIN V14881, 1 each

6. Hose assembly, 1-12 in., 11-1/2 National Pipe Standard Hose (NPSH), 10 ft, 7 each

7. Hose assembly, rubber water, braided, 1 in., 11-1/2 NPSH, 10 ft, 2 each

8. Hose, textile fiber, rubber-lined, 300 psi, 1 in., 11-1/2 NPSH, 25 ft, 1 each

9. Valve, plug, three-way selector, 1-1/2 in., National Pipe Threads (NPT), 1 each

10. Valve, flow control, orifice type, 3/4 in., 14 NPT, 8 gal/min, 1 each

11. Nipple, pipe: brass, 1 in. diameter, 2 in. long, 1 each

12. Tee, pipe: brass, 1-1/2 in., 1 each

13. Nipple, pipe: brass, 1-1/2 in. diameter, 2-1/2 in. long, 2 each

14. Valve, gate: bronze, 1-1/2 in., 2 each

15. Adapter, straight, pipe to hose: 1-1/2 in., 11-1/2 NPT external, 1-1/2 in. 1-1/2 NPSH, external, 2 each

16. Float, ball type: plastic, 8-in. diameter, 2 each

Table A1

Job Task Analysis Summary

Nomenclature FIELD LAUNDRY WASTEWATER RECYCLING SYSTEMS Date 13 Nov 1984

Task Steps Identification and Analysis

Task Ident.	Task Description	Step No.	Step Description	Equipment
1.1.1	Clear operating site	1	Remove loose rocks and debris from the operating site.	
		2	Cut and remove bushes and trees, as necessary, from the operating site.	1. Axe 2. Saw
1.1.2	Level equipment positions	1	Using a pick and shovel, level ground in the selected places where the wastewater, treatment, and holding tanks will be located.	1. Pick 2. Shovel
1.1.3	Excavate disposal sump	1	Using a pick and shovel, dig a hole about 2 ft deep and 2 ft in diameter. NOTE: The disposal sump should be located within 10 ft of each of the two treatment tanks.	1. Pick 2. Shovel
1.2.1	Install wastewater collection tank	1	Place wastewater collection tank on the ground in its prepared location.	1. Bladder tank, 500-gal

Table A1 (Cont'd)

Nomenclature FIELD LAUNDRY WASTEWATER RECYCLING SYSTEMS Date 13 Nov 1984

Task Steps Identification and Analysis

Task Ident.	Task Description	Step No.	Step Description	Equipment
		2	Connect hose from laundry unit discharge to wastewater collection tank inlet.	2. Hose assembly, 1-1/2 in., 1/2NPSH, 10 ft long
1.2.2	Install wastewater transfer pump	1	Place transfer pump in its operating position.	1. Transfer pump
		2	Connect hose between wastewater collection tank outlet and transfer pump inlet.	2. Hose assembly 1-1/2 in., 11-1/2 NPSH, 10 ft long, 2 each
		3	Add fuel to transfer pump fuel tank.	3. Fuel for transfer pump.
		4	Connect 20 ft of hose to pump discharge.	4. Hose assembly, rubber water braided. 1 11-1/2 NPSH, 10 ft long.
				NOTE: Above items are part of laundry wastewater treatment kit. 4610-01-023-4536 (SC 4610-97-CL-E14)

Table A1 (Cont'd)

Nomenclature FIELD LAUNDRY WASTEWATER RECYCLING SYSTEMS

Date 13 Nov 1984

Task Steps Identification and Analysis

Task Ident.	Task Description	Step No.	Step Description	Equipment
1.2.3	Install wastewater treatment tanks	1	Position tank in its prepared location.	1. Tank, fabric, collapsible, nylon, water, 500 gal., 2 each
		2	Install stakes.	
		3	Insert wooden staves.	2. Hose assembly, 1-1/2 in., 11-1/2 NPSH, 10 ft long, 3 each
		4	Install guy ropes.	
		5	Repeat for second tank.	3. Tee pipe, brass 1-1/2 in., 1 each
		6	Connect hoses, gate valves, and tee between tanks.	4. Nipple, pipe, brass, 1-1/2 in., dia., 2-1/2 in. long, 2 each
		7	Connect hose between tee and transfer pump inlet.	5. Valve, gate, bronze 1-1/2 in., 11-1/2 NPT, 2 each
				6. Adapter, straight, pipe to hose, 1-1/2 in., 11-1/2 NPSH ext., 2 each
				NOTE: Above items are part of laundry wastewater treatment kit. 4610-01-023-4536 (SC 4610-97-CL-E14)

Table A1 (Cont'd)

Nomenclature FIELD LAUNDRY WASTEWATER RECYCLING SYSTEMS   Date 13 Nov 1984

Task Steps Identification and Analysis

Task Ident.	Task Description	Step No.	Step Description	Equipment
1.2.4	Install filter unit	1	Place filter in its operating position.	1. Filter unit, diatomaceous earth, 420 GPH
		2	Connect 20 ft of suction hose to filter unit.	2. Hose assembly, rubber, water braided, i in., 11-1/2 NPSH, 10 ft long, 2 each
		3	Connect float to other end.	3. Float, ball-type plastic, 8-in. dia.
		4	Place suction hose and float into one of the treatment tanks.	4. Nipple, pipe, brass 1 in. dia., 2 in. long
		5	Install pipe nipple into filter unit discharge.	5. Valve, flow control, orifice type, 1 in. NPT, 8 gal/min, with bushings
		6	Install flow control valve onto pipe nipple.	
1.2.5	Install laundry water storage tank	1	Position tank in its prepared location.	1. Tank, fabric, collapsible, nylon, water, 1500 gal

Table A1 (Cont'd)

Nomenclature FIELD LAUNDRY WASTEWATER RECYCLING SYSTEMS Date 13 Nov 1984

Task Steps Identification and Analysis

Task Ident.	Task Description	Step No.	Step Description	Equipment
		2	Install stakes.	2. Hose, textile fiber, rubber-lined, 1 in., 11-1/2 INSH, 25 ft long
		3	Insert wooden staves.	
		4	Install guy ropes.	
		5	Connect hose between flow control valve outlet and tank (place hose outlet over top of 500-gal tank).	
1.2.6	Install laundry unit pump	1	Place pump in its operating position.	1. Laundry unit pump and hose (part of field laundry unit)
		2	Connect suction hose to pump inlet.	2. Float, ball-type, plastic, 8-in. dia.
		3	Connect float ball to inlet end of suction hose and place in laundry water storage tank.	
		4	Connect discharge hose between pump discharge and laundry unit inlet.	

Table A1 (Cont'd)

Nomenclature FIELD LAUNDRY WASTEWATER RECYCLING SYSTEMS Date 13 Nov 1984

Task Steps Identification and Analysis

Task Ident.	Task Description	Step No.	Step Description	Equipment
1.2.7	Install generator	1	Place generator in its operating position.	1. Generator set, 1.5-Kw, 509-hv GED
		2	Drive ground rod into ground.	2. Power cable (part of filter unit)
		3	Connect ground cable between generator set and ground rod.	3. Ground rod
		4	Connect power cable between generator and filter unit.	4. Ground cable
				5. Sledge hammer
		5	Add fuel to generator set fuel tank	6. Ground rod clamp
				7. Adjustable wrench
1.3.1	Chemically treat wastewater	1	Open wastewater collection tank discharge valve.	1. 8 lb of powdered activated carbon
		2	Set three-way plug valve to the "transfer" position.	2. 100 mL of sulfuric acid or 100 mL of dry sodium carbonate
		3	Start the transfer pump.	
				3. 75 mL of cationic polyelectrolyte (type I polymer)

Table A1 (Cont'd)

Nomenclature FIELD LAUNDRY WASTEWATER RECYCLING SYSTEMS　　Date 13 Nov 1984

Task Steps Identification and Analysis

Task Ident.	Task Description	Step No.	Step Description	Equipment
		4	Measure pH of wastewater.	4. 1 g of nonionic polyelectrolyte (type II polymer)
		5	Adjust pH of wastewater.	
		6	Add 8 lb of powdered carbon to the treatment tank.	5. Timer (30-min or greater capacity)
		7	When the transfer is complete, close the wastewater collection tank discharge valve. to the "recirculate" position	NOTE: Timer not in current equipment listing for Pollution Abatement Kit.
		8	Set the three-way plug valve to the "recirculate" position.	
1.3.2	Filter treated water	1	Start generator.	1. Diatomaceous earth
		2	Mix diatomite slurry in bucket; pour into filter shell.	
		3	Start filter unit pump.	
		4	Precoat filter elements.	

Table A1 (Cont'd)

Nomenclature FIELD LAUNDRY WASTEWATER RECYCLING SYSTEMS Date 13 Nov 1984

Task Steps Identification and Analysis

Task Ident.	Task Description	Step No.	Step Description	Equipment
		5	Operate filter water to 40 psi.	
		6	Backwash filter; stop filter unit pump.	
		7	Stop generator.	
1.3.3	Chlorinate filtered water	1	Add calcium hypochlorite to water in storage tank.	1. Calcium hypochlorite
		2	Stir.	2. Wooden paddle
		3	Measure residual chlorine.	3. Color comparator
1.3.4	Dispose of accumulated sludge	1	Scoop sludge from bottom of treatment tank.	1. Sludge scoop
		2	Dump sludge into disposal sump.	
1.4.1	Disassemble field laundry wastewater recycling system.	1	Drain and rinse wastewater treatment tanks.	
		2	Shut down generator.	

Table A1 (Cont'd)

Nomenclature FIELD LAUNDRY WASTEWATER RECYCLING SYSTEMS Date 13 Nov 1984

Task Steps Identification and Analysis

Task Ident.	Task Description	Step No.	Step Description	Equipment
		3	Disconnect electric cables.	
		4	Drain wastewater collection tank.	
		5	Drain laundry water storage tank.	
		6	Remove guy ropes, stakes, and wooden staves from collapsible tanks.	
		7	Collapse tanks.	
		8	Disconnect and drain water from all hoses, valves, and fittings.	
1.4.2	Stow field laundry waste water recycling system	1	Roll up hoses.	1. Storage bags
		2	Place all items in their respective storage bags.	2. Truck/trailer
		3	Load equipment onto truck/trailer.	

Table A2

Job Data Worksheet

JOB TITLE OPERATOR MOS 57E PAGE NO. ___

DUTY/CODE LAUNDRY & BATH SPECIALIST LEVEL ________ DATE 21 Nov 84

Item Code	Task, Elements (JPM)	Conditions	Initiating Cues	Standards	Notes
1.1.1	Clear operating site	In a field environment	Given an unimproved operating site	Clear the site of rocks, debris, and vegetation in accordance with Para __, TM_________.	Provide ax, saw, and TM.
1.1.2	Level equipment positions	In a field environment	Given a cleared operating site	Level the ground position for the collection, treatment, and storage tanks in accordance with Para __, TM __________.	Provide pick, shovel and TM.
1.1.3	Excavate disposal sump	In a field environment	Given a cleared and leveled operating site	Excavate a disposal sump in accordance with Para__, TM	Provide pick, shovel, and TM. __________.
1.2.1	Install wastewater collection tank	At a field operating site	Given a field laundry wastewater recycling system and a prepared operating site	Install the wastewater collection tank in accordance with Para ____, TM_________.	Provide wastewater collection tanks, inlet hose assembly, and TM.

Table A2 (Cont'd)

JOB TITLE OPERATOR MOS 57E PAGE NO. ___

DUTY/CODE LAUNDRY & BATH SPECIALIST LEVEL ___ DATE 21 Nov 84

Item Code	Task, Elements (JPM)	Conditions	Initiating Cues	Standards	Notes
1.2.2	Install waste-water transfer pump	At a field operating site	Given a field wastewater recycling system with wastewater collection tank installed	Install the waste-water transfer pump in accordance with Para ___, TM ___ ___.	Provide transfer pump, hoses, fuel, and TM.
1.2.3	Install waste-water treatment tanks	At a field operating site	Given a field wastewater recycling system with the wastewater transfer pump installed	Install the waste-water treatment tanks in accordance with Para ___, TM ___.	Provide treatment tanks, hoses, valves, fittings, and TM.
1.2.4	Install filter unit	At a field operating site	Given a field laundry wastewater recycling system with the waste-water treatment tanks installed	Install the filter unit in accordance with Para ___, TM ___.	Provide filter unit, hose, nipple, float valve, and TM.
1.2.5	Install laundry water storage tank	At a field operating site	Given a field laundry wastewater recycling system with the filter unit installed	Install the laundry water storage tank in accordance with Para ___, TM ___.	Provide tank, hose, and TM.

Table A2 (Cont'd)

JOB TITLE OPERATOR ____ MOS 57E ____ PAGE NO. ____

DUTY/CODE LAUNDRY & BATH SPECIALIST LEVEL ____ DATE 21 Nov 84

Item Code	Task, Elements (JPM)	Conditions	Initiating Cues	Standards	Notes
1.2.6	Install laundry unit pump	At a field operating site	Given a field laundry wastewater recycling system with the laundry water storage tank installed	Install the laundry unit pump in accordance with Para ___, TM ______.	Provide pump, hose, float, and TM.
1.2.7	Install generator	At a field operating site	Given a field laundry wastewater recycling system with all plumbing installed	Install the generator in accordance with Para____, TM__________.	Provide generator, power cable, ground rod clamp, ground cable, adjustable wrench, sledge hammer, and TM.
1.3.1	Chemically treat wastewater	At a field operating site	Given an operational field laundry wastewater recycling system with a full wastewater collection tank and empty treatment tank	Chemically treat wastewater in accordance with Para_____, TM__________.	Provide powdered activated carbon, cationic polyelectrolyte, nonionic polyelectrolyte, sulfuric acid, timer, and TM.
1.3.2	Filter treated water	At a field operating site	Given an operational field laundry wastewater recycling system with treated water in one or both treatment tanks	Filter the treated wastewater in accordance with Para______, TM__________.	Provide diatomaceous earth, bucket, measure, and TM.

Table A2 (Cont'd)

JOB TITLE OPERATOR ____ MOS 57E ____ PAGE NO. ____

DUTY/CODE LAUNDRY & BATH SPECIALIST LEVEL ____ DATE 21 Nov 84

Item Code	Task, Elements (JPM)	Conditions	Initiating Cues	Standards	Notes
1.3.3	Chlorinate filtered water	At a field operating site	Given an operational field laundry wastewater recycling system with filtered water in the laundry water storage tank	Chlorinate the filtered water in accordance with Para ____, TM____.	Provide calcium hypochlorite, measure, wooden paddle, color comparator, and TM.
1.3.4	Dispose of accumulated sludge	At a field operating site	Given an operational field laundry wastewater recycling system with inches of sludge accumulated in either or both of the treatment tanks	Dispose of the sludge in accordance with Para____, TM____.	Provide sludge scoop and TM.
1.4.1	Disassemble field laundry wastewater recycling system	At a field operating site	Given an operational field laundry wastewater recycling system and orders to prepare the system for movement	Disassemble the system in accordance with Para ___, TM ____.	
1.4.2	Stow field laundry wastewater recycling system	At a field operating site	Given a disassembled field laundry wastewater recycling system	Stow the system in accordance with Para____, TM____.	Provide storage bags, truck/trailer, and TM.

PERSONNEL PLANNING DATA

Task frequencies listed herein are predicted values of task occurrence per mission based on an assumed mission length of 10 days and an operating schedule of 20 hours per day (one operator per shift, three shifts per day).

Total man-minutes identified in the task schedule include productive time per task only; nonproductive time (i.e., time spent waiting for mixing, sedimentation, etc.) is not included.

PERSONNEL PLANNING DATA

FIELD LAUNDRY WASTEWATER RECYCLING SYSTEM

Nomenclature

Part Number

23 Nov 84
Date

TASK	Operation Maintenance					Personnel							Elapsed Time Minutes				Frequency	Task Schedule	
	OPER	Maintenance				Rating Navy	MOS/ AFSC	No. Pers by Skill					B	I	A	Total		Unsched.	Sched.
		*	F(DS)	H(GS)	D			B	I	A	Total								

*OPER = Operator; F(DS) = Field (Direct Support); H(GS) = Heavy (General Support); D = Depot; B = Basic; I = Intermediate; A = Advanced.

PERSONNEL PLANNING DATA

FIELD LAUNDRY WASTEWATER RECYCLING SYSTEM

Nomenclature

Part Number

23 Nov 84
Date

TASK	Operation Maintenance					Personnel						Elapsed Time Minutes				Frequency	Task Schedule	
	OPER	Maintenance				Rating	MOS/	No. Pers by Skill				B	I	A	Total		Unsched.	Sched.
		O	F(DS)	H(GS)	D	Navy	AFSV	B	I	A	Total							
1.1.1	X						57E	1				30			30	1		30
1.1.2	X						57E	1				30			30	1		30
1.1.3	X						57E	1				10			10	1		10
1.2.1	X						57E	2				5			5	1		10
1.2.2	X						57E	2				5			5	1		10
1.2.3	X						57E	2				15			15	1		30
1.2.4	X						57E	2				5			5	1		10
1.2.5	X						57E	2				10			10	1		20
1.2.6	X						57E	2				5			5	1		10
1.2.7	X						57E	2				15			15	1		30

PERSONNEL PLANNING DATA

FIELD LAUNDRY WASTEWATER RECYCLING SYSTEM

Nomenclature: ______ Part Number: ______ Date: 23 Nov 84

TASK	Operation Maintenance: OPER	Operation Maintenance: O	Maintenance: F(DS)	Maintenance: H(GS)	Maintenance: D	Personnel: Rating Navy	Personnel: MOS/APSV	No. Pers by Skill: B	No. Pers by Skill: I	No. Pers by Skill: A	No. Pers by Skill: Total	Elapsed Time Minutes: B	Elapsed Time Minutes: I	Elapsed Time Minutes: A	Elapsed Time Minutes: Total	Frequency	Task Schedule: Unsched.	Task Schedule: Sched.
1.3.1	X						57E	1				75			75		80	10
1.3.2	X						57E	1				70			70		80	10
1.3.3	X						57E	1				15			15		80	15
1.3.4	X						57E	1				15			15		10	15
1.4.1	X						57E	2				45			45		1	90
1.4.2	X						57E	2				15			15		1	30

SECTION III. TRAINING ANALYSIS SUMMARY

Operator Course

The objective of the FLWRS operator course is to train laundry and bath specialists (MOS 57E) to perform the following tasks at a field operating site:

1. Install the FLWRS to a fully operational condition in not more than 1 hour.

2. Operate the FLWRS to renovate wastewater from field laundry unit(s) such that the renovated water can be continuously reused by the unit(s).

3. Disassemble and stow the FLWRS in accordance with TM ________.*

Field Laundry Wastewater Recycling System Installation

1.2 At a field operating site, given a disassembled but otherwise fully operable FLWRS, install the FLWRS to a fully operational condition in accordance with Technical Manual ___, with the assistance of one additional soldier within 1 hour.

1.2.1	Install the wastewater collection tank in accordance with the technical manual.	1. Follow written instructions. 2. Interpret mechanical drawings. 3. Use common hand tools. 4. Identify wastewater collection tank inlet and laundry water discharge hose. 5. Assemble threaded plumbing connections.
1.2.2	Install the wastewater treatment tanks, in accordance with the technical manual.	1. Follow written instructions. 2. Interpret mechanical drawings. 3. Use common hand tools. 4. Identify all components of collapsible fabric water tanks. 5. Identify common plumbing connections.

*Refers to technical manual to be produced upon Army approval of FLWRS.

1.2.3	Install the filter unit in accordance with the technical manual.	1.	Follow written instructions.
		2.	Interpret mechanical drawings.
		3.	Use common hand tools.
		4.	Identify all components of the filter unit.
		5.	Identify common plumbing items.
		6.	Assemble threaded plumbing connections.
1.2.4	Install the laundry water holding tank, in accordance with the technical manual.	1.	Follow written instructions.
		2.	Interpret mechanical drawings.
		3.	Use common hand tools.
		4.	Identify all components of collapsible fabric water tanks.
		5.	Assemble threaded plumbing connections.

Field Laundry Wastewater Recycling System Operation

1.3 At a field operating site, given a fully assembled and operational FLWRS, operate the FLWRS in accordance with Chapter ___ of the technical manual to renovate wastewater from field laundry unit(s) such that the renovated water can be continuously reused by the field laundry unit(s).

1.3.1	Chemically treat the wastewater in accordance with the technical manual.	1.	Follow written instructions.
		2.	Measure pH of water samples.
		3.	Measure liquid and dry chemicals.
		4.	Adjust the pH of water to desired levels.
		5.	Operate gas-engine-driven pumps.
		6.	Operate three-way and gate valves.
		7.	Operate mechanical, electric, or electronic timers.

1.3.2	Filter the treated water in accordance with the technical manual.	1.	Follow written instructions.
		2.	Operate gas-engine-driven generator sets.
		3.	Operate mechanical, electric, or electronic timers.
1.3.3	Chlorinate the filtered water in accordance with the technical manual.	1.	Follow written instructions.
		2.	Measure pH of water samples.
		3.	Measure dry chemicals.
		4.	Calculate quantity of calcium hypochlorite required.
		5.	Measure residual chlorine concentration of water samples.

Preparation for Movement

1.4 At a field operating site, given an assembled FLWRS, disassemble and stow the FLWRS in accordance with Para___, Technical Manual______.

1.4.1	Disassemble the FLWRS in accordance with the technical manual.	1.	Follow written instructions.
		2.	Interpret mechanical drawings.
		3.	Use common hand tools.
		4.	Identify all components of the FLWRS.
1.4.2	Stow the FLWRS in accordance with the technical manual.	1.	Follow written instructions.
		2.	Interpret mechanical drawings.
		3.	Identify all components of the FLWRS.

SECTION IV. MANPOWER SUMMARY

A. Installation

The FLWRS can be installed in 1 hour by two persons (one MOS 57E10 with one helper, and one MOS nonspecific).

B. Operation

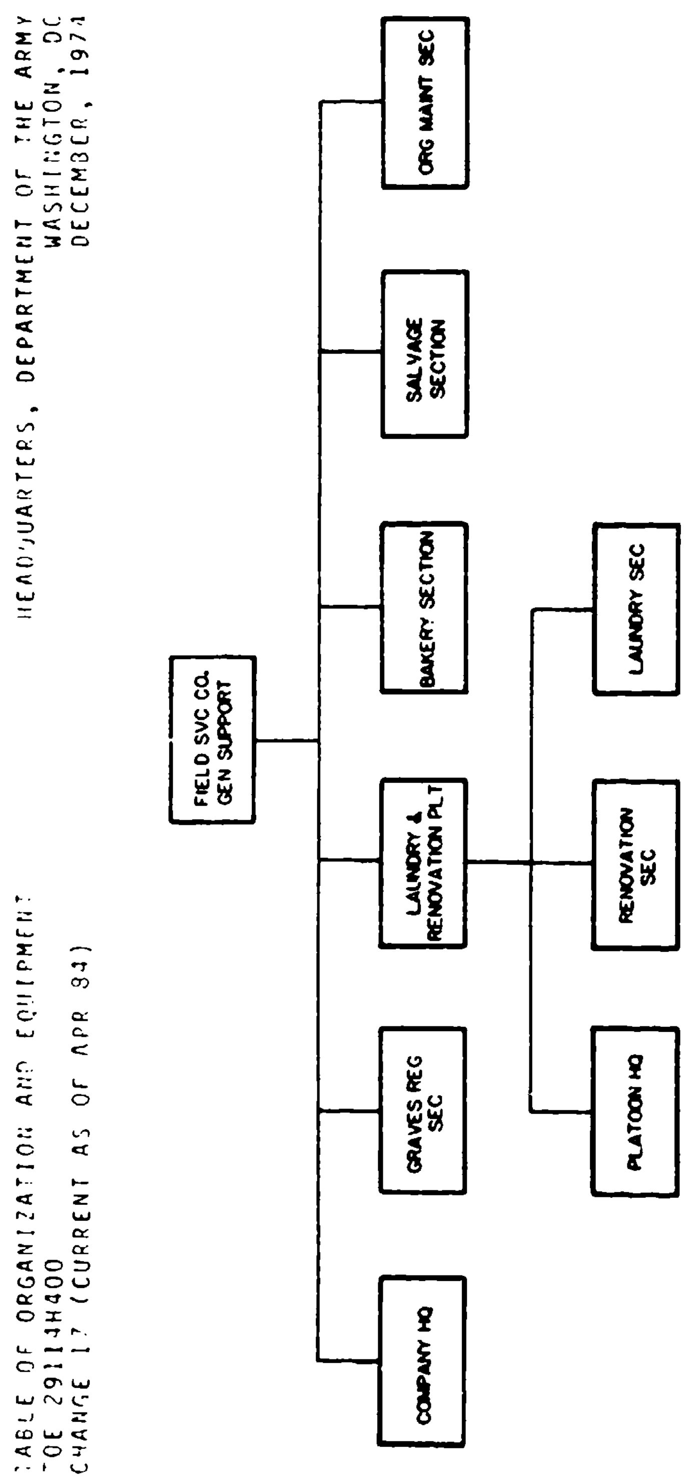
All operator tasks for the FLWRS can be performed by one operator (MOS 57E10). An operating crew of three (MOS 57E10) would be required for a 20-hour-per-day operating schedule. The FLWRS operators would be supervised by the laundry team supervisor.

C. Maintenance

All FLWRS components are currently in the Army inventory within various other systems. Maintenance requirements for these components are already established and therefore were not included in this report.

APPENDIX B:

EXCERPT FROM TABLE OF ORGANIZATION AND EQUIPMENT FIELD SERVICE COMPANY, GENERAL SUPPORT, FORWARD TOE 29114H400 CHANGE 17 (CURRENT AS OF APRIL 1984)



SECTION II

PARA	LINE/LDI	CHG NO	ERC	DESCRIPTION	GRADE	MOS	BR	DCPC	ASI/RMKS 1	ASI/RMKS 2	ASI/RMKS 3	ASI/RMKS 4	STRENGTH LEVELS 1	STRENGTH LEVELS 2	STRENGTH LEVELS 3	AUG A	TYPE B	C
	[illegible]	07	C	CAMERA SET STILL PICTURE KS-99									1	1	1		1	
	[illegible]	12	A	GEN ST DSL ENG 10KW 60HZ 1-3PH AC 120/208 120/240V TAC UTIL							522		2	2	2		2	
	T47141	08	C	SIGN PAINTING KIT: W/COMPONENTS									1	1	1		1	
	[illegible]	08	C	TOOL KIT CARPENTERS ENGINEER SQUAD W/CHEST									1	1	1		1	
	[illegible]	07	B	TRAILER CARGO: 1-1/2 TON 2 WHEEL W/E									2	2	2		2	
	[illegible]	07	B	TRUCK CARGO: 2-1/2 TON 6X6 W/E									2	2	2		2	
03		07		DELETE														
04		07		DELETE														
05				LDRY-RENV PLATOON HQ														
	01	10		PLATOON LEADER	LT	62A00	QM	P4					1	1	1		1	
	02	08		PLATOON SERGEANT	E-7	57E40	NC	P4					1	1	1		1	
	03	07		DELETE														
	04	07		REPORTS CLERK	E-3	71L10		P4	01				1	1	1		1	
				PARA TOTAL									3	3	3		3	
05	C[illegible]01	16	B	CHARGER RADIAC DETECTOR PP-4370/PD									1	1	1		1	
03				RENOVATION SECTION														
	01	07		FABRIC REPAIR NCO	E-6	43M30	NC	P4					1	1	1		1	
	02	07		DELETE														
	03	07		FABRIC REPAIR SP	E-5	43M20		P4					3	3	3		3	
	04	07		FABRIC REPAIR SP	E-4	43M10		P4	01				7	8	8		7	
	06	07		FABRIC REPAIR SP	E-3	43M10		P4					7	8	5		7	
				PARA TOTAL									18	18	15		11	

TABLE OF ORGANIZATION AND EQUIPMENT
TOE 29114H400
CHANGE 17
FIELD SVC CO, GS, FWD

HEADQUARTERS, DEPARTMENT OF THE ARMY
WASHINGTON, DC
DECEMBER, 1974

SECTION II

PARA	LIN/LRI	CNG NO	ERC	DESCRIPTION	GRADE	MOS	BR	DCPC	ASI/RMKS 1	2	3	4	STRENGTH LEVELS 1	2	3	AUG A	TYPE B	CADRE C
	E4[illegible]1	03	A	CLOTHING REPAIR SHOP: TRLR MTD 2 WHL LESS POWER									2	2	2		2	
	J4[illegible]	07	B	GEN SET GAS ENG 3KW 60HZ 1-3PH 120/240 120/208V SKD TAC UTILITY									2	2	2		2	
	U[illegible]814	07	B	TABLE FOLDING LEGS: LABORATORY									2	2	2		2	
	X4[illegible]	03	B	TRUCK CARGO: 2-1/2 TON 6X6 W/E									1	1	1		1	
07				3 LAUNDRY SECTIONS														
	01	05		SECTION CHIEF	E-5	57E20	NC	P4					3	3	3		3	
	02	05		DELETE														
	03	07		LAUNDRY SPECIALIST	E-4	57E10		P4					18	18	15		18	
	04	07		DELETE														
	05	05		DELETE														
	06	07		LAUNDRY SPECIALIST	E-3	57E10		P4	01	06			21	21	18			
	07	07		DELETE														
				PARA TOTAL									42	42	36		21	
	L48315	08	A	LAUNDRY UNIT TRAILER MOUNTED: SINGLE TRAILER 60 LB CAP									6	6	6		6	
	N04282	07	A	PIN SET MARKING LAUNDRY: 8 PIN CARRIERS 3840 MARKED PINS									3	3	3		3	
	P62030	08	A	PUMP CENTRF: GAS DRVN FRAME MTD 2 IN 125 GPM 50 FT HD									3	3	3		3	
	V15018	08	A	TANK FABRIC COLLAPSIBLE: WATER 3000 GAL									3	3	3		3	
	V19050	12	B	TANK UNIT LIQUID DISPENSING TRAILER MOUNTING									3	3	3		3	
	W95811	12	B	TRAILER CARGO: 1-1/2 TON 2 WHEEL W/E									3	3	3		3	
	X40794	12	B	TRUCK CARGO: DROP SIDE 5 TON 6X6 W/E									3	3	3		3	
03		07		DELETE														

APPENDIX C:

PROGRAM OF INSTRUCTION FOR OPERATION AND OPERATOR MAINTENANCE OF FIELD LAUNDRY WASTEWATER RECYCLING SYSTEM

SECTION I. PREFACE

A.	Course:	Operation and Operator Maintenance of Field Laundry Wastewater Recycling System (FLWRS) - Proposed
B.	Purpose:	To provide enlisted personnel with the knowledge and skills required to deploy and operate the FLWRS, and to perform operator maintenance
C.	Prerequisite:	Assignment as instructor or operator of a field laundry unit
D.	Length:	Peacetime - 5 days
E.	Training Location:	To be determined
F.	MOS Feeder Pattern:	Prerequisite MOS Operator 57E
G.	Ammunition Requirement:	No ammunition required

F. MOS trained in this course: Same as prerequisite

SECTION II. SUMMARY

Course: Operation and Operator Maintenance of Field Laundry Wastewater Recycling System (FLWRS) - Proposed

Hours: 40

		Hours	Annex*
A. Academic Subjects:	Operation and operator maintenance	40	A
B. Nonacademic Subjects:	Not applicable		

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*See Section IV, p 94.

C. Recapitulation:

Type of instruction:

Conference	11
Lead-through practical exercise	25
Examinations	4

SECTION III. BODY

Course: Operation and Operator Maintenance of Field Laundry Wastewater Recycling System (FLWRS) - Proposed

Academic Subjects: 40 hours

Annex Title and Subjects	Hours	Annex
Operation and Operator Maintenance		A
Introduction to Course, Operation, and Operator Maintenance	2	A
Deployment of FLWRS	3	A
Operation and Maintenance of FLWRS	29	A
Disassembly and Stowing of FLWRS	2	A
Performance and Written Examination	4	A
Total Hours:	40	

SECTION IV. ANNEXES

Annex A: Operation and Operator Maintenance

Purpose: To provide the student with the required course objectives, performance standards, publication references, equipment, and component descriptions to operate and maintain the FLWRS at the Operator level.

File No.	Classification	Type of Instruction

FLWRS-A-010-010 - Introduction to Operation and Operator Maintenance

Hours: 2 U* 2C**

Objective: In a training environment, given course material, referenced technical manual, and the FLWRS, the student will:

(a) Identify referenced publications and state their applications in this lesson

(b) State the purpose, capabilities, features, and technical principles of operation

(c) Identify the components and their function and location in the system

(d) Relate the components of the FLWRS to the technical manual reference.

Completion of tasks will be verified by an instructor as specified in technical manual reference.

References: Technical manual on FLWRS.

*Unclassified.
**2 Classroom hours.

File No.	Classification	Type of Instruction

FLWRS-A-010-020 - Deployment of FLWRS 1C, 2 LTPE*

Objective: At a field operating site, given a disassembled but otherwise fully operable FLWRS, the necessary tools and materials, technical manual, and a student workbook, the student will:

(a) Assemble the FLWRS

(b) Identify the components of the system

(c) Identify key features of each component

(d) Perform preventive maintenance checks and services on the FLWRS.

References: Technical manual
Student workbook.

*Lead Through Practical Exercise.

File No.	Classification	Type of Instruction

FLWRS-A-010-030 - Operation and Maintenance of the FLWRS

Hours: 29	U	8C, 21 LTPE

Objective: At a field operating site, given a fully assembled and operational FLWRS and technical manual, the student will:

(a) Perform preventive maintenance checks and services on the FLWRS

(b) Operate the FLWRS

(c) Perform water sampling and testing procedures

(d) Perform troubleshooting on the FLWRS

(e) Perform the FLWRS diagnostic program

(f) Perform operator maintenance on the FLWRS.

Performance and completion of tasks will be verified by an instructor.

References: Technical manual
Student workbook.

File No.	Classification	Type of Instruction

FLWRS-A-010-040 - Disassembly and Stowing of FLWRS

Hours: 2	U	2 LTPE

Objective: At a fie d training site, given an assembled FLWRS, the student will:

(a) Disassemble and prepare the FLWRS for movement to another operating location

(b) Prepare the FLWRS for storage.

Performance and completion of tasks will be verified by an instructor as specified in the technical manual.

References: Technical manual
Student workbook.

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105
01/86

File No.	Classification	Type of Instruction

FLWRS-A-010-050 - Performance and Written Examinations

Hours: 4	U	4 EI

Objective: In a training environment, given a fully assembled and operational FLWRS, the student will:

(a) Identify key features of the technical manual and their application

(b) Demonstrate knowledge of the purpose, capabilities, and features of the FLWRS

(c) Demonstrate knowledge of technical principles of operation

(d) Identify components and their location on the FLWRS. and in the manual

(e) Perform preventive maintenance checks and services tasks and procedures

(f) Conduct one complete treatment cycle using the FLWRS

The student will demonstrate knowledge and perform the above tasks without error in accordance with the technical manual. The student's performance will be evaluated by an instructor using references listed below.

References: Technical manual
Written instructions.

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